MAP REPORT 82-1

GEOLOGY OF JUNIPER - KNOWLESVILLE - CARLISLE AREA MAP AREAS I-16 I-17 I-18 (Parts of 21 J/11 and 21 J/06)

by

C. ST. PETER

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GEOLOGY OF JUNIPER-KNOWLESVILLE-CARLISLE AREA NEW BRUNSWICK

MAP-AREAS I-16, I-17, and I-18

(Parts of 21J/11 and 21J/6)

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GEOLOGICAL SURVEYS BRANCH

DEPARTMENT OF NATURAL RESOURCES

NEW BRUNSWICK

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ABSTRACT

The Juniper-Knowlesville-Carlisle map-area lies 40 km northeast of Woodstock and encompasses 500 km^2 of western New Brunswick. The area is mostly underlain by deformed Ordovician to Devonian sedimentary and volcanic rocks of the Matapedia Basin. The eastern rocks of the Basin are intruded by a Devonian gabbro pluton and several smaller bodies of felsic rocks. In the northeast, the Basin rocks are in thrust contact along the Catamaran Fault with polydeformed Cambrian and Lower Ordovician rocks of the Miramichi Anticlinorium. In the south, rocks of the Basin are unconformably overlain by post-Acadian Carboniferous strata.

The Basin sequence comprises the Carys Mills, Smyrna Mills, Costigan Mountain, and Wapske Formations. The deep water carbonate rocks of the Carys Mills Formation contain Late Ordovician to Early Silurian graptolites. The shelf clastics and carbonates of the Smyrna Mills Formation yield Middle Silurian conodonts and Middle to Upper Silurian graptolites. The Costigan Mountain ignimbrites and lava flows have sedimentary interbeds containing plant fragments and marine icnogenera. The Wapske Formation clastics yield early middle Lower Devonian photic zone brachiopods in the lower part and late Lower to early Middle Devonian terrestrial spores and the branchiopod, *Euestheria raymondi*, in the upper part.

The eastern part of the Basin sequence is unconformably underlain by the Craig Brook Limestone (new name) containing excellent assemblages of Middle Ordovician conodonts. The Craig Brook rocks are predominantly shallow water carbonates. They are correlated with Llanvirn (early Middle Ordovician) limestone and greywacke exposed within the Miramichi Anticlinorium 30 km southwest of the map-area.

The post-Acadian sequence consists of minor terrestrial mafic volcanics, Mississippian Carlisle Formation (new name) alluvial fan redbeds, and Pennsylvanian Mountain View Formation (new name) grey, quartzose fluvial beds.

Several thrust faults have been documented. Most of the thrusts dip to the west; others, related to the Catamaran Fault, dip to the east. The west-dipping faults are related to the regional Woodstock Fault; all have at least a component of movement that post-dates the Mississippian Carlisle Formation. The west-dipping Ashland-Highlands and Knowlesville Faults define tectonic boundaries that account for differences in Acadian structural trends in the area.

In the past, Ordovician and Silurian sedimentary sequences have been explored for quarriable limestone. The Silurian Smyrna Mills Formation has been examined for sedimentary iron and manganese deposits. Devonian felsic volcanic and intrusive rocks have been given cursory examination for porphyry copper and base metal potential.

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GEOLOGY OF JUNIPER-KNOWLESVILLE-CARLISLE AREA

NEW BRUNSWICK

INTRODUCTION

The Juniper-Knowlesville-Carlisle map-area is located about 40 km northeast of Woodstock, New Brunswick (Figure 1). The area encompasses approximately 500 km^2 on three, one inch to one quarter mile scale maps: I-16 (Argyle-Juniper), I-17 (Knowlesville-Armond), and I-18 (North Branch Becaguimec-Carlisle-Cloverdale). The maps, with their accompanying plate numbers, are bound by the following latitudes and longitudes:

Map-Area	Plate Number	Latitudes North	Longitudes West
I-16	80-35A	46°36'; 46°30'	67°12'; 67°24'
I-17	80-36A	46°30'; 46°24'	67°12'; 67°24'
I-18	80-37A	46°24'; 46°18'	67°12'; 67°24'

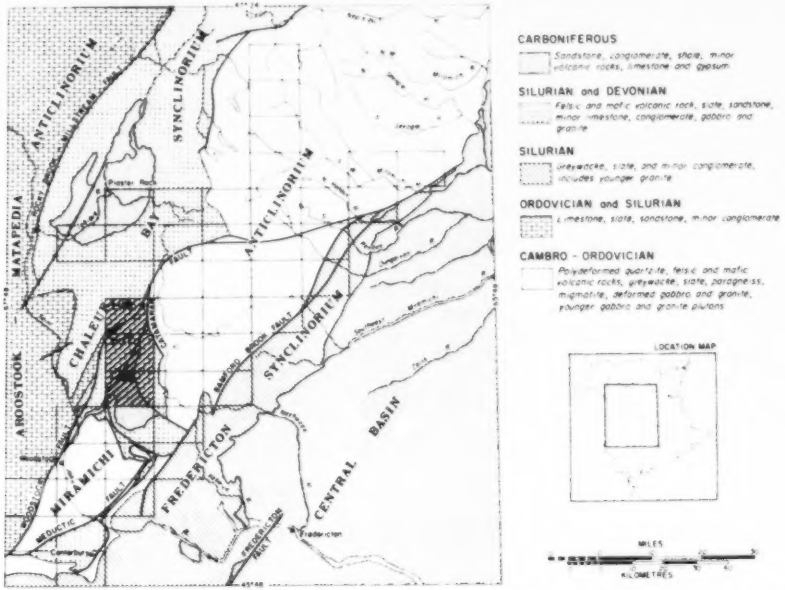


Figure 1. Index map showing location of I-16, I-17, and I-18 map-areas (shaded).

Access to the north part of the area is provided by paved secondary Highway 107 leading east from Bristol to Juniper. There are several public gravel roads off Highway 107. Access to the south and west parts of the area is provided by Highway 575 leading east from Hartland to Carlisle and Cloverdale. The east side of the area can be reached with a 4-wheel drive vehicle via roads running south from Juniper and east and northeast from North Becaguimec River.

The rocks in the area were examined during the summers of 1979, 1980, and 1981. Outcrops along roads and streams were initially examined. Pace and compass traverses using 1:20,000 scale aerial photographs were employed to provide correlation in geologically more complex areas.

The writer was capably assisted in the field by Anne Trepanier, Karen Lees, and James Lockhart. Editorial assistance was given by L.R. Fyffe, J.B. Hamilton, and Dr. A.A. Ruitenberg, all of the New Brunswick Department of Natural Resources. Special acknowledgements are extended to project coordinator L.R. Fyffe for periodic field assistance and numerous stimulating discussions.

Diane Blair typed the manuscript and performed other related duties. Ronald Phillips drafted the maps and figures.

Several paleontologists have contributed to a more complete understanding of the geology. Among them, special thanks are extended to A.J. Boucot for the identification of brachiopods, G.S. Nowlan for the separation and documentation of conodonts, A. Lenz for the identification of graptolites, and D.C. McGregor for the separation and examination of spores.

Several geologists carried out exploratory surveys in this area of New Brunswick during the nineteenth century. The work of Bailey (1886) is particularly significant. He broadly divided the rocks into five formations - all of which more or less stand as originally proposed. Matthews and Bailey (*op. cit*) discovered fossils in a sequence of Ordovician rocks along North Becaguimec River one hundred years ago that have been largely overlooked by succeeding geologists. Caley (1936) further refined the units proposed by Bailey and gave a general description of the iron and limestone occurrences between Woodstock and Glassville. The limestone beds were examined in greater detail by Anderson (1968) as part of 1:50,000 scale survey encompassing NTS quadrangles Millville (21 J/3), Woodstock (21 J/4), and Coldstream (21 J/6).

This report was funded under a Provincial-Federal development project. During the project the rocks to the east of the report area were studied by Lutes (1981) and St. Peter (1981) and to the south by Venugopal (1981). The rocks to the west of the Knowlesville and Carlisle area were examined by St. Peter during 1981. The 1:50,000 scale maps of that area have been published (St. Peter 1982*a*, *b*).

The central purpose of the present investigation was to re-examine the Ordovician to Devonian sedimentary and volcanic rocks in the light of recent advances in regional stratigraphy (see Hamilton-Smith 1972; St. Peter 1978*a*, 1981). Within the area it will be shown that the Cambrian-Ordovician sequence of

Anderson (*op. cit*) to the west of the Becaguimec Lake Gabbro, is an intercalated sequence of Lower Devonian felsic volcanic and minor plant-bearing sedimentary rocks. The previously undivided Silurian and Devonian sequence is here divided into four formations: (1) the Middle Ordovician Craig Brook Limestone, (2) the Upper Ordovician-Lower Silurian Carys Mills Formation, (3) the Silurian Smyrna Mills Formation, and (4) the Lower Devonian Wapske Formation. In the course of subdividing the Ordovician to Devonian sedimentary rocks, it has been discovered that faults, and in particular thrust faults, have greatly complicated the distribution of rock formations.

PHYSIOGRAPHY

The map-area lies on the boundary between two major physiographic divisions - the New Brunswick Highlands to the east and Chaleur Uplands to the north and west (Bostock 1970). The Highlands comprise a chain of rounded hills underlain by the Becaguimec Lake Gabbro and Costigan Mountain Formation (Figure 2). Elevations in this area range from 350 to 500 m above mean sea level with Brighton Mountain at 554 m being the highest summit (note that the contours on the Plates are given in feet). The Highlands slope northwest towards South Branch Southwest Miramichi River and southwest towards North Becaguimec River.

Shikatehawk River in the northwest, Cold Stream in the west, and Brummagen Brook in the central part of the area have eroded deeply into sedimentary rocks. Most other streams are marked by U-shaped valleys.

In the southern part of the area, a prominent plateau approximately 350 m above mean sea level is underlain by quartzose sedimentary rocks of the Carboniferous Mountain View Formation. The plateau rises about 150 m above local base level along an escarpment which follows North Becaguimec River in the northeast and Day Brook in the west (Figure 3).

The land along the secondary roads from Biggar Ridge in the north to Armond in the southwest supports several small grain and potato farms. A few farms are also located in the Carlisle-Cloverdale area. Most of the area, however, is covered by a mixed coniferous and deciduous forest that has been commercially harvested near Shikatehawk River in the northwest.

REGIONAL GEOLOGICAL SETTING

The Juniper-Knowlesville-Carlisle area is underlain by rocks of two regional northeast-trending tectonostratigraphic zones: the Matapedia Basin in the west, and the Miramichi Anticlinorium or Massif in the east (McKerrow and Ziegler 1971; Rodgers 1970; Rast and Stringer 1975; Fyffe *et al.* 1981). The Matapedia Basin has traditionally been subdivided into three subzones from the northwest to the southeast: Gaspé Synclinorium, Aroostook-Matapedia Anticlinorium, and Chaleur Bay Synclinorium (Rodgers 1970; Rast and Stringer 1975; Ruitenberg *et al.* 1977).

PENNSYLVANIAN

Mountain View Formation

P$_s$ — *Grey quartzose sandstone and quartz pebble conglomerate*

MISSISSIPPIAN

Carlisle Formation

M$_s$ — *Red polymictic pebble - cobble conglomerate, red lithic sandstone, minor red mudstone locally containing limestone nodules, minor red breccia and grey arkose*

Unnamed Formation

Mm_v — *Dark gray, amygdaloidal mafic volcanic rocks*

DEVONIAN

Juniper Barrel Granite

Dt_3 — *Pink and grey, medium- grained, biotite granite*

Dt_2 — *Dt_2 , pink, fine- to medium grained, monzogranite and quartz monzonite, pink to grey, biotite quartz feldspar porphyry, minor pink microgranite, and quartz monzodiorite*

Dt_1 — *Light grey, medium- grained granodiorite containing xenoliths of hornfelsic siltstone and sandstone*

Dm_3 — *Dark grey, fine grained, diabasic gabbro, minor quartz diorite*

Dm_2 — *Grey and pink, medium grained, quartz monzodiorite*

Becaguimec Lake Gabbro

Dm_1 — *Dark green and white, medium- grained, subophitic gabbro, minor gabbro pegmatite and granodiorite veins*

LOWER DEVONIAN

TOBIQUE GROUP

Wapske Formation

Ds_2/Dm_2 — *Ds_2, dark gray slate and siltstone interbedded with grey sandstone and grey pebble - cobble polymictic conglomerate*

Dm_2, dark green, amygdaloidal mafic volcanic rocks, minor sedimentary rocks

Costigan Mountain Formation

Ds_1/Dm_3 — *Ds_1, dark grey siltstone interbedded with grey quartzose sandstone, and minor polymictic conglomerate*

Dm_3, dark green, amygdaloidal mafic volcanic rocks

Df_3, pink rhyolitic feldspar porphyry, pink rhyolitic quartz- feldspar porphyry, pink lapilli rhyolitic tuff, minor pink eutaxitic rhyolitic tuff

SILURIAN

Smyrna Mills Formation

S$_{sm}$ — *Ss, green slate, green and grey siltstone, green and grey calcareous sandstone, minor red slate, gray graptolitic siltstone, green quartzose sandstone orange weathering, calcareous quartzose siltstone, grey lithic wacke and conglomerate, light grey limestone, and felsic volcanic rocks*

Sm$_v$, dark green amygdaloidal mafic volcanic rocks

UPPER ORDOVICIAN - LOWER SILURIAN

Carys Mills Formation

OSs — *Thinly interbedded light grey weathering limestone and dark calcareous slate*

MIDDLE ORDOVICIAN

Craig Brook Limestone

Us — *Grey crystalline limestone, grey lithographic limestone, dark grey chert, and dark grey calcareous slate, minor quartzose sandstone and dolomite*

LOWER ORDOVICIAN

Of — *Mottled pink and grey, mylonitic granite*

Om — *Dark green and light grey, banded amphibolite*

CAMBRIAN - ORDOVICIAN

<COp — *Mottled light and dark grey, medium- grained, cataclastic paragneiss*

Geological boundary (approximate)

Reverse or thrust fault (approximate) teeth in direction of dip

Fault (approximate)

Anticline, approximate trace of axial surface

Syncline, approximate trace of axial surface

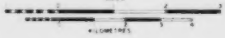
KEY

1-16

1-17

1-18

Geology by C. St Peter, 1979-1981 (revised 1981)



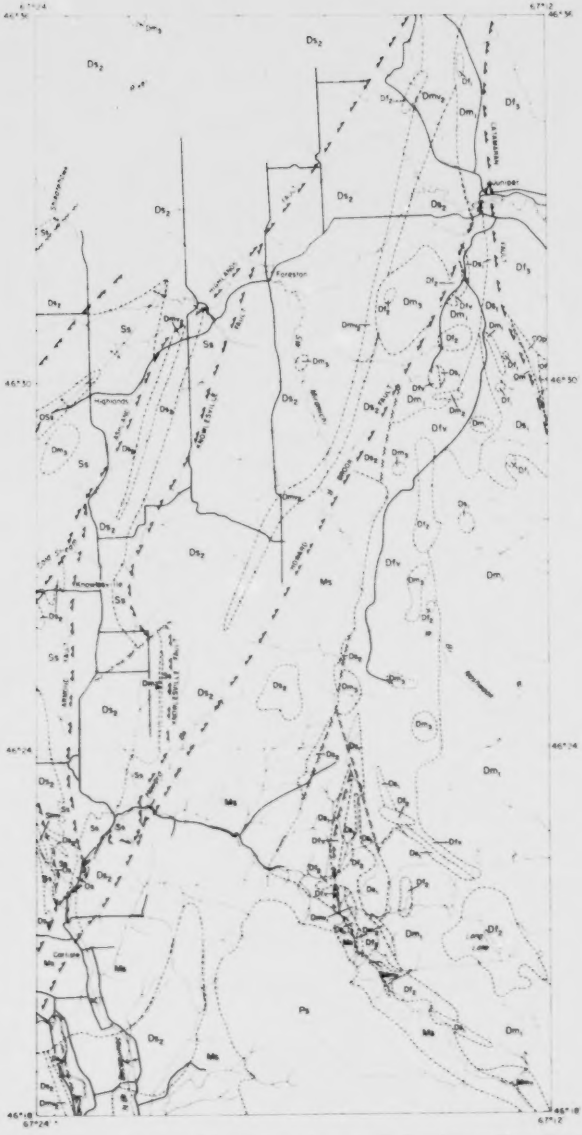


Figure 2. Generalized geology of Juniper-Knowlesville-Carlisle area, New Brunswick.

Figure 3. View looking southeast from northwestern I-18 map-area showing low-lying Carlisle Formation along North Becaguimec River. The quartzose sandstones of the Mountain View Formation form the escarpment in the left background. The low wooded ridge in the right foreground is underlain by the Smyrna Mills Formation.

The tectonostratigraphic zonations relevant to the report-area are the Aroostook-Matapedia Anticlinorium and Chaleur Bay Synclinorium sub-zones of the Matapedia Basin and the Miramichi Anticlinorium (Figure 1).

The Miramichi Anticlinorium extends from Woodstock in the south to Bathurst in the north. The Anticlinorium is underlain by a complex association of Cambrian-Ordovician polydeformed greenschist to amphibolite facies quartzose and pelitic sedimentary rocks, and deformed Ordovician gabbro, granite, greywacke, slate, and mafic volcanic rocks. The anticlinorium has been affected by the polyphase Ordovician Taconian Orogeny (Poole 1976) and by the Middle Devonian Acadian Orogeny. The polydeformed rocks are intruded by a suite of syn- to post-kinematic Devonian granite plutons and minor gabbro stocks. The Miramichi Anticlinorium is in fault contact with the Chaleur Bay Synclinorium along most of its length. However, in the Portage Lake area of northern New Brunswick Upper Silurian conglomerate and grit of the Chaleur Group unconformably overlie the polydeformed rocks (Helmstaedt 1971).

The Chaleur Bay Synclinorium extends from Canterbury in the south to Chaleur Bay in the north - a distance of 250 km (Figure 1). The synclinorium is largely formed of folded Silurian and Devonian sedimentary and volcanic rocks. In the Canterbury area, the succession comprises the Canterbury Limestone, Pocowogamis Conglomerate, Scott Siding Slate, Dorrington Hill mafic volcanic rocks, and Hartin Formation slate and sandstone (Venugopal 1979; Lutes 1979). South of Chaleur Bay in northern New

Brunswick the synclinorium is defined by folded sedimentary and volcanic rocks of the Silurian Chaleur Group and the Lower Devonian Dalhousie Group (Alcock 1935; Greiner 1970; Lee and Noble 1977). In west-central New Brunswick between the Rocky Brook-Millstream Fault and Miramichi Anticlinorium (Figure 1), the Chaleur Bay Synclinorium comprises a thick folded sequence of felsic volcanic, mafic volcanic, and sedimentary rocks of the Lower Devonian Tobique Group (St. Peter 1978*a*, 1981). The Silurian-Devonian rocks of the Synclinorium are locally intruded by Devonian dykes and stocks of subporphyritic biotite±hornblende granite and granodiorite and by dykes, stocks, and a pluton (Becaguimec Lake Gabbro) of gabbro, diorite, and monzodiorite (Fyffe *et al.* 1981).

In the southern part of the Chaleur Bay Synclinorium, the Tobique Group is unconformably overlain by two outliers of Carboniferous redbeds. The redbeds are exposed near Plaster Rock and Carlisle (Figure 1 and 2), and are confined to small intermontane basins.

The Aroostook-Matapedia Anticlinorium extends from the Houlton area of eastern Maine to the Percé area of eastern Gaspé Peninsula in Quebec (Boucot *et al.* 1964). Within New Brunswick the Aroostook-Matapedia Anticlinorium comprises folded Ordovician clastic rocks of the Grog Brook Group, upper Ordovician-Silurian limestone of the Carys Mills Formation, and minor infolded Silurian clastic rocks of the Smyrna Mills and Perham Formations (Pavlides 1968; Hamilton-Smith 1970, 1972; St. Peter 1978*b*). Like the rocks within the Chaleur Bay Synclinorium, the rocks in the Matapedia Anticlinorium were folded and cleaved by the Middle Devonian Acadian Orogeny. The rocks in these two tectonic zones form a conformable sequence that is locally broken by faults.

The northeastern part of the Juniper-Knowlesville-Carlisle area is underlain by rocks of the Miramichi Anticlinorium. The Catamaran Fault separates the Miramichi Anticlinorium from the Chaleur Bay Synclinorium to the west. In the extreme west, a northeast-trending anticline cored by limestone of the Carys Mills Formation defines the easternmost exposure of the Aroostook-Matapedia Anticlinorium in the area (Figure 2).

An angular unconformity separating Middle Ordovician from Upper Ordovician and Silurian rocks has been documented in the southern part of the Chaleur Bay Synclinorium during recent mapping. The Middle Ordovician rocks, herein called the Craig Brook Limestone, are exposed in four small inliers. Two inliers occur near North Becaguimec River (Figure 2), the other two a short distance to the west of the map-area (St. Peter 1982*b*).

The bedrock geology within the Juniper-Knowlesville-Carlisle area is summarized on Figure 2; the local stratigraphic succession is given in Table 1.

STRATIGRAPHY

CAMBRIAN-ORDOVICIAN

Paragneiss (Unit €Op): A narrow layer of paragneiss

TABLE 1.

Table of Formations.

Era	System/ Series	Formation and thickness (m)	Map Unit	Lithology
PALEOZOIC	Pennsylvanian	Mountain View Formation 170+	Ps	Grey quartzose sandstone and quartz pebble conglomerate
	Mississippian	Carlisle Formation 150-200	Ms	Red polymictic conglomerate, red lithic sandstone; minor red mudstone, red breccia and grey arkose
		Unnamed Formation 20	Mmv	Dark grey, amygdaloidal mafic volcanic rock
	UNCONFORMITY			
	Devonian	Juniper Barren Granite	Df_3	Pink and grey, medium-grained biotite granite
			Df_2	Pink, fine- to medium-grained, monzogranite and quartz monzonite, pink to grey biotite-quartz-feldspar porphyry; minor pink microgranite, and quartz monzodiorite
			Df_1	Light grey, medium-grained granodiorite
			Dm_3	Dark grey, fine-grained, diabasic gabbro; minor quartz-diorite
			Dm_2	Grey and pink, medium-grained, monzodiorite
		Becaquimec Lake Gabbro	Dm_1	Dark green and white, medium-grained, subophitic gabbro; minor gabbro pegmatite, and granodiorite veins
	INTRUSIVE CONTACT			
	Lower Devonian	Wapske Formation 4000(?)	Ds_2	Interbedded dark grey slate, dark grey siltstone, grey sandstone, and grey polymictic pebble-cobble conglomerate
			Dmv_2	Dark green, amygdaloidal, mafic volcanic rock
		Costigan Mountain Formation 1000(?)	Ds_1	Interbedded dark grey siltstone and light grey quartzose sandstone; minor conglomerate gabbro and granodiorite
			Dmv_1	Dark green, amygdaloidal, mafic volcanic rocks; minor sedimentary rocks
			Dfv	Pink, subtrachytic feldspar- and quartz-feldspar porphyry, pink, lapilli rhyolitic tuff; minor eutaxitic rhyolitic tuff
	Silurian	Smyrna Mills Formation 600-900	Ss	Green slate, green and grey siltstone, green and grey calcareous sandstone; minor red slate, graptolitic siltstone, green quartzose sandstone, orange-weathering, calcareous quartzose siltstone, grey lithic wacke, pebble conglomerate, light grey limestone, and felsic volcanic rock
			Smv	Dark green, amygdaloidal, mafic volcanic rock
	Upper Ordovician-Lower Silurian	Carys Mills Formation 200+	OSs	Thinly interbedded light grey, arenaceous limestone and dark grey calcareous slate
	UNCONFORMITY WITH SMYRNA MILLS FORMATION			
	Middle Ordovician	Craig Brook Limestone	Os	Grey lithographic limestone and crystalline limestone, dark grey chert and calcareous slate; minor quartzose sandstone and dolomite
	FAULT CONTACT WITH TOBIQUE GROUP			
	Lower Ordovician		Of	Mottled pink and grey mylonitic granite
			Om	Dark green and light grey, banded amphibolite
	Cambrian-Ordovician		COp	Mottled light and dark grey, medium-grained, cataclastic paragneiss

occurs east of the Catamaran Fault and south of the Juniper Barren Granite (Unit Df_3) in southeastern I-16 map-area and northeastern I-17 map-area. To the east and north of the Juniper Barren Granite similar paragneiss and associated granitoid constitute a widespread suite of rocks that have been described by St. Peter (1981), Crouse (1981), and Lutes (1981).

The paragneiss is a mottled light and dark grey, fine medium-grained, cataclastic rock containing 10 to 15 per cent porphyroclasts of plagioclase and 15 to 20 per cent porphyroclasts of alkali feldspar. The plagioclase porphyroclasts range from 0.5 to 2 mm in diameter; they are rounded, broken, sheared, and some show recrystallized margins. The alkali feldspar porphyroclasts range from 0.5 to 7 mm in length; they comprise both microcline and orthoclase perthite and show deformational fabrics similar to plagioclase. The matrix of the paragneiss consists of 35 per cent quartz, 15 per cent plagioclase, 15 per cent potash feldspar, 20 per cent biotite, 10 per cent cordierite, accessory opaque mineral(s), and zircon. Cordierite occurs as rounded and elongate xenoblasts (Figure 4) that are fractured and rotated within a cataclastic foliation defined by parallel oriented biotite and elongate patches of polygonized quartz. Some cordierite crystals are replaced by pinite and overgrown by unoriented sericite. Biotite has been recrystallized following cataclasis and forms polygonal aggregates with no evidence of strain. Biotite is partially replaced by chlorite.

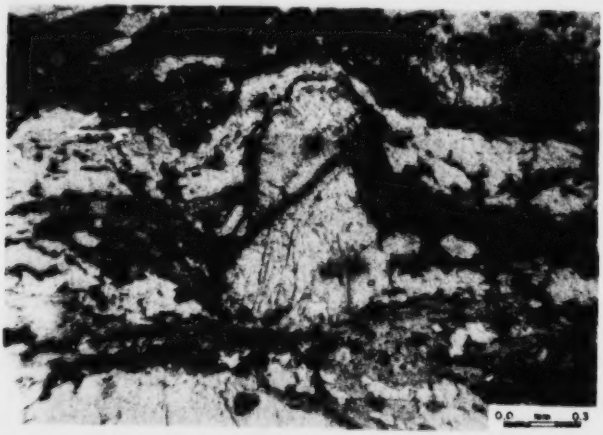


Figure 4. Rotated cordierite xenoblast enveloped by recrystallized quartz and lenticular biotite.

The paragneiss is intruded by concordant sills and stocks of foliated granite similar to Unit Of. The paragneiss is seen to be intruded by the Juniper Barren Granite 8 km northeast of Juniper (St. Peter 1981).

Both the age of deposition and metamorphism of the paragneiss is uncertain. Similar cordierite- and sillimanite-bearing rocks to the east have been correlated with biotite grade

psammite and pelite that have known affinity with pre-Early Ordovician quartzites and slates (St. Peter 1981; Crouse 1981).

LOWER ORDOVICIAN

Crdovician amphibolite and granite occur east of the Catamaran Fault within the Miramichi Anticlinorium in southeastern I-16 map-area and northeastern I-17 map-area.

Amphibolite (Unit Om): The amphibolite forms an elongate body about 4 km in length and 125 m in width adjacent to the Catamaran Fault. The rock is mottled buff and dark green on weathered surfaces and dark grey on fresh surfaces. It has a conspicuous banding defined by compositionally and texturally distinct alternating layers ranging from less than 1 cm to greater than 30 cm in thickness (Figure 5). About 60 to 70 per cent of the amphibolite consists of dark green, fine-grained layers with equigranular lepidoblastic texture. These layers comprise 60 per cent hornblende, 30 per cent plagioclase (andesine), 5 per cent opaque mineral(s), accessory zircon and sphene. The hornblende has a subparallel orientation defining a foliation. The lepidoblastic layers alternate with buff blastoporphyritic layers containing about 15 per cent rounded relict andesine crystals varying from 0.3 to 4 mm in diameter (Figure 6). Besides relict andesine, the blastoporphyritic layers contain 35 per cent plagioclase, 20 per cent hornblende, 20 per cent biotite, 5 per cent quartz, accessory opaque mineral(s), zircon and apatite. Biotite and quartz are restricted to the blastoporphyritic layers. In both layers hornblende is partially replaced by chlorite and epidote; plagioclase is partially replaced by sericite, incipient epidote and clinozoisite.

Figure 5. Banded and folded amphibolite.

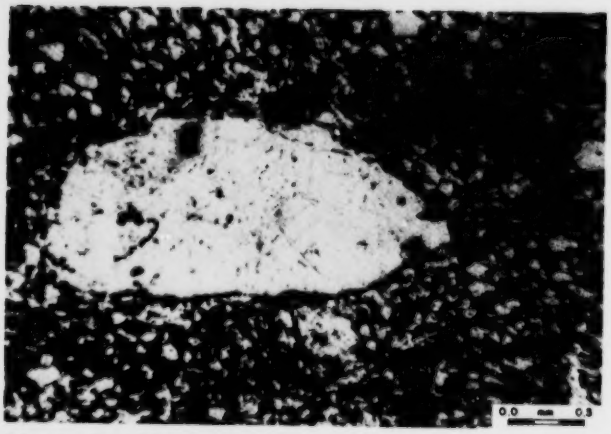


Figure 6. Blastoporphyritic texture of amphibolite showing relict andesine in a fine-grained matrix of aligned hornblende, biotite, and plagioclase.

The amphibolite is juxtaposed against greenschist grade sedimentary rocks of the Lower Devonian Costigan Mountain Formation along the Catamaran Fault. On Little Clearwater Brook in northeastern I-17 map-area, the amphibolite is interlayered and infolded with mylonitic granite of Unit Of. About 30 km northeast of Little Clearwater Brook banded amphibolite is intruded by foliated augen granite (St. Peter 1981). Similar foliated granite in the Sevogle River area of northeastern New Brunswick has yielded an Early Ordovician age (Fyffe *et al.* 1977). The regional correlation of foliated granite, and its known intrusive relationship with the amphibolite, strongly suggest that the latter rock is Early Ordovician in age.

Mylonitic Granite (Unit Of): The mylonitic granite in southeastern I-16 and northeastern I-17 map-areas is a mottled dark grey and pink, fine-grained rock with a well developed moderately dipping foliation (Figure 7). The rock contains about 10 per cent oligoclase porphyroclasts and 15 per cent alkali feldspar porphyroclasts in a fine-grained mylonitic matrix of quartz, biotite, plagioclase, orthoclase, hornblende, accessory sphene, apatite, and opaque minerals. The plagioclase and alkali feldspar (orthoclase and microcline) porphyroclasts are rounded, strained, granulated and recrystallized along their borders. The porphyroclasts range from 0.3 to 10 mm in diameter. Quartz in the matrix occurs as sheared irregular to lenticular patches, and along with biotite defines a well developed mylonitic foliation enveloping the porphyroclasts (Figure 8). Both quartz and biotite have been recrystallized to polygonized aggregates following cataclasis. The granite contains about 1 per cent small porphyroblasts of blue-green hornbelnde that post-date the foliation. The foliation is cut by very narrow veins containing quartz, sphene, epidote, and clinozoisite.

Figure 7. Moderately dipping foliation in mylonitic granite on Little Clearwater Brook.

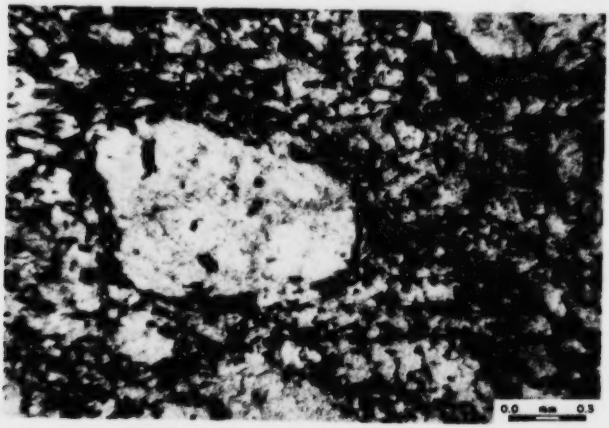


Figure 8. Mylonitic granite showing porphyroclast of plagioclase enclosed by aligned biotite, quartz and plagioclase.

To the east of I-16 and I-17 map-areas and away from the Catamaran Fault the mylonitic granite grades into non-mylonitic but regionally foliated feldspar augen granite that has been described by St. Peter (1981) and Lutes (1981).

Along Little Clearwater Brook in northeastern I-17 map-area the mylonitic granite is infolded with amphibolite, but there their age relationship could not be determined. Elsewhere, in the Miramichi Anticlinorium the granite is seen to intrude similar amphibolite and amphibolitic gabbro (St. Peter 1981).

The mylonitic granite and associated augen granite are given an Early Ordovician age based on lithological and structural correlation with similar granite in north-central New Brunswick that gives a Rb-Sr whole rock isochron age of 479±14 Ma using a half-life of 4.88 X 10^{10} years (Fyffe *et al.* 1977).

MIDDLE ORDOVICIAN

Craig Brook Limestone (Unit Os): A sequence of Ordovician limestone and associated interbedded fine-grained rocks is found as two lenses in I-18 map-area. One occurs about 700 m up Craig Brook and the other extends from the mouth of Craig Brook northward along the banks of North Becaguimec River and then inland where it crosses a small brook on the west side of the river about 1 km north of the mouth of Craig Brook. The Ordovician rocks are herein assigned the name Craig Brook Limestone.

The enigmatic presence of pre-Silurian rocks along North Becaguimec River was first recognized by G.F. Matthews in 1880 (*In* Bailey 1886). Both Matthews and Bailey were able to retrieve from the "slates ... and flinty calcareous layers" fragmentary brachiopods referable to *Leptaena*, *Lingulella*, *Strophomena*, and *Discina*. Bailey (p. 25G, *op. cit.*) recovered the trilobite *Cryptolithus* (Harpes) which led him to correlate the beds with the Trenton Group of southern Ontario.

Hamilton (1965) partially delineated the limestone body from surface exposures and diamond drill logs submitted by Stratmat Limited in 1955. Hamilton noted that the presence of Late Silurian graptolites in contiguous rock suggested a time gap between the Ordovician and Silurian sequences.

The Craig Brook Limestone comprises interstratified silty lithographic limestone and dark grey calcareous slate with interbeds of crystalline limestone, carbonaceous quartzose sandstone, banded chert and dolomite. The lithographic limestone occurs in light grey-weathering beds ranging from 1 to 51 cm in thickness. The rock is characterized by numerous calcite veins and well developed graphitic stylolites. Some beds show a tendency to pinch and swell giving the layers a distinctive lumpy appearance - a feature commonly called sedimentary boudinage. The slate interbeds are dark grey and graphitic; they range from 1 to 10 cm in thickness. The slate and limestone have a distinctive ribboned appearance (Figure 9).

From thin section examinations the lithographic limestone is seen to consist of mostly calcite spar with an average grain size of 0.03 mm. Set in the spar is very fine-grained sand

Figure 9. Folded Craig Brook Limestone on North Becaguimec River.

detritus of quartz, plagioclase, muscovite, and partially recrystallized oolites, pellets, and microlaminated calcite clasts. The latter are possibly pieces of disrupted algal mats. The interbeds of dark grey calcareous slate are largely composed of silt-size carbonate grains containing oolites and microcrenulated and laminated calcite clasts. The oolites display relict concentric structure. The microlaminated calcite fragments are in part disrupted; some lie oblique to bedding.

Massive beds of grey crystalline limestone occur along North Becaguimec River and in an exposure on a small brook to the northwest. The rock occurs in beds 10 cm to several metres in thickness. A thin section from the exposure on the small brook indicates the limestone consists of about 50 per cent carbonate sand (0.04 to 0.8 mm) set in a blocky calcite cement. The sand clasts comprise mostly micritic pellets and/or intraclasts with minor fragmented oolites, bryozoans, coral debris(?), and microlaminated calcite. The rock also contains very abundant conodonts (see fossil locality 97516, Table 2).

On North Becaguimec River, 200 to 400 m above the mouth of Craig Brook, the lithographic limestone and calcareous slate contain a few interbeds of dark grey, fine-grained, carbonaceous, quartzose sandstone, light and dark grey, parallel-laminated chert and minor associated mottled, light and dark grey, crystalline dolomite. The chert and dolomite contain randomly oriented large crystals of metamorphic wollastonite. The dolomite also displays minor "patches" of radiating chalcedony. Poorly preserved graptolites, that are typically displayed as graphitic films, have been recovered from the carbonaceous sandstones.

A considerable difference in age exists between the Craig Brook Limestone and the adjacent Smyrna Mills Formation,

TABLE 2.

Conodonts from Craig Brook Limestone.

Species \ Locality	97516	98596	98006	97514	98624
Latitude	46°22'25"N	46°22'10"N	46°22'00"N	46°18'50"N	46°23'15"N
Longitude	67°22'35"W	67°22'51"W	67°23'29"W	67°25'45"W	67°25'42"W
Belodina sp.	X				
Belodina? sp.		X			
Dapsilodus similaris (Rhodes) s.l.		X			
Drepanoistodus sp.		X			
Drepanoistodus [illegible] (Sergeeva)	X				
Eoplacognathus elongatus (Bergström)	X				
Eoplacognathus cf. *E. elongatus* (Bergström)				X	
E. lindstroemi (Hamar)		X			
E. n. sp.		X			
Oistodus sp.			X		
O. venustus Stauffer		X			
"Oneotodus" sp.			X		
Panderodus sp.	X		X		
P. gracilis (Branson & Mehl)		X			X
P. cf. *P. gracilis* (Branson & Mehl)	X			X	
Paroistodus? mutatus (Branson & Mehl)				X	X
Periodon aculeatus Hadding	X	X		X	X
Prioniodus gerdae Bergström	X				
Prioniodus prevariabilis? Fåhraeus				X	
P. variabilis Bergström	X	X			
Protopanderodus varicostatus (Bergström & Sweet)	X	X		X	X
P. sp.	X	X		X	
Pygodus sp. (haddingodiform element)		X			
P. anserinus (Lamont & Lindström)	X				
P. cf. *P. anserinus* (Lamont & Lindström)				X	
P. serrus (Hadding)					X
Scalpellodus sp.		X			
S. cavus (Webers)					X
"Scolopodus" peselephantis Lindström		X		X	
Spinodus ramosus (Hadding)		X			
Strachanognathus parvus Rhodes		X		X	X
Walliserodus sp.				X	X
W. cf. *W. amplissimus* (Serpagli)			X		
W. nakholmensis (Hamar)	X	X			

thus implying the contact between the formations is a fault or an unconformity. The basal (eastern) contacts of the two Craig Brook sequences in I-18 map-area are known to be tectonic (see below under "Structural Geology"). The upper (western) contacts are interpreted to be unconformable. Rocks along Craig Brook, very near the western contact of the more westerly sequence, show no evidence of shearing. About 850 m northeast of Craig Brook, an outcrop of Smyrna Mills limestone within a few metres of the contact contains limestone pebbles presumably derived from the Craig Brook sequence. An unconformity between the Craig Brook Limestone and Late Ordovician limestone has recently been documented in the Markey Brook area 3 km west of Craig Brook (St. Peter 1982*b*).

The Craig Brook Limestone has been sampled for conodonts at three localities in northwestern I-18 map-area. Locality 97516 (latitude 46°22'25"N; longitude 67°22'35"W) is from a bed of crystalline limestone along the south bank of a small brook on the west side of North Becaguimec River. The sample yielded over 300 well preserved conodont specimens. The assemblage, given in Table 2, was determined by Nowlan (1981*a*); his comments are given below.

> "The fauna is numerically dominated by specimens of *Panderodus* and *Prioniodus*. Two species of *Prioniodus* are present: *P. variabilis* and *P. gerdae*. The occurrence of both forms together suggests a transitional phase, although the two species are quite distinctive. Each species characterizes a subzone of the *Amorphognathus tvaerensis* zone of Caradocian age (Figure 10). The age of the assemblage therefore appears to be early Caradoc belonging to the early part of the *Prioniodus gerdae* Subzone.
>
> *Eoplacognathus elongatus* is known to range as high as the lower part of the *P. gerdae* Subzone, and serves to confirm an early *P. gerdae* Subzone (precise early Caradoc) age.".

Locality 98596 (latitude 46°22'10"N; longitude 67°22'51" W) is from a bed of silty lithographic limestone from an exposure on the west bank of North Becaguimec River, 800 m north-northeast of the mouth of Craig Brook. The sample provided more than 600 specimens. The assemblage, as determined by Nowlan (1981*c*) is given in Table 2. Nowlan (*ibid.*) writes, "this very diverse fauna is numerically dominated by ... long-ranging species *Dapsilodus similaris* and *Periodon aculeatus*. The occurrence of a single specimen referable to *Pygodus* indicates a Llanvirn to Llandeilo age. This can be further refined by ... *Eoplacognathus lindstroemi* which is known to range from the upper part of the *Pygodus serrus* Zone (Figure 10) through most of the *P. anserinus* Zone (Bergström 1971) thus suggesting a late Llanvirn to Llandeilo age.".

The limestone at locality 98596 has also yielded a few ostracodes which Copeland (1981) identifies as:

Winchellatia?
Euprimitia
"Bythocypris"?
cf. *Pseudulrichia* sp. or cf. *Klimphores* sp.

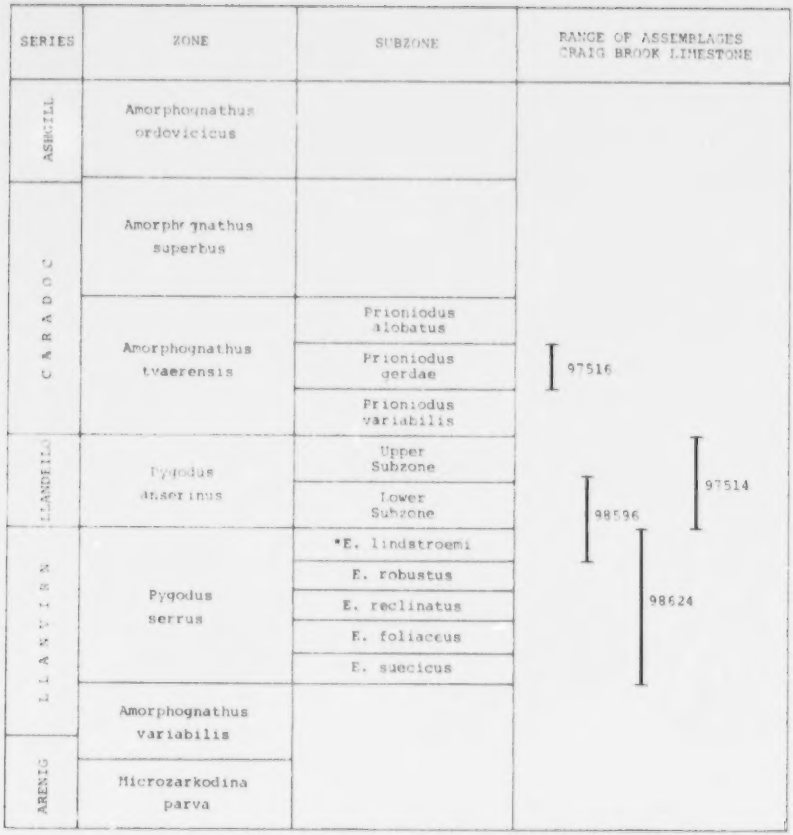


Figure 10. Ordovician conodont zones and subzones (after Bergström 1971 and Lindström 1971).

Copeland (*ibid.*) writes: "At present *Winchellatia* and related very similar European genera appear to be restricted to the Middle and Upper Ordovician and *Klimphores* (a Baltic genus) to the Middle Ordovician.".

Another sample of crystalline limestone collected 700 m upstream on Craig Brook at locality 98006 (latitude 46°22'00"N; longitude 67°23'29"W) yielded 12 fragmentary conodont specimens assigned to taxa listed in Table 2.

According to Nowlan (1981*b*) "This restricted fauna suggests an Ordovician age based on the presence of two morphotypes of *Oistodus*, one of which is similar to *O. venustus* Stauffer and

*Eoplacognathus

the other which is similar to oistodiform elements of *Prioniodus* apparatuses. The presence of *Panderodus* suggests that the sample is of Middle or Upper Ordovician rather than Lower. The specimens assigned to *Walliserodus* are most similar to *W. amplissimus*, an upper Ordovician form but the identification cannot be confirmed on this sparse material. Thus the sample is of Ordovician age, probable middle to late.".

When the Craig Brook Limestone was sampled for conodonts, a sample was also collected from a limestone quarry near Ashland. The quarry lies near the headwaters of Mill Brook, about 7 km southwest of the mouth of Craig Brook at latitude 46°18'50"N and longitude 67°25'45"W (St. Peter 1982*b*). Although the limestone there lies outside the present map-area, it seems appropriate to report the excellent conodont assemblage recovered.

The rock at the quarry is a dark grey, carbonaceous, stylolitic, crystalline limestone in a bed at least 30 m in thickness (Figure 11). Conodonts retrieved from the limestone (locality 97514) are listed in Table 2. Nowlan (1981*a*) reports that: "The sample yielded over 200 moderately well preserved specimens. The fauna is numerically dominated by *Periodon aculeatus* and *Panderodus* cf. *P. gracilis*. *P. aculeatus* ranges from Llanvirn through at least Llandeilo. The form referred to *Pygodus* cf. *P. anserinus* shows a poorly developed fourth denticle row. A form such as this is usually considered to be early in the evolutionary development of *P. anserinus* and suggests an early Llandeilo age (Figure 10).

Figure 11. Styolitic limestone, Ashland quarry.

The forms referred to *Eoplacognathus* cf. *E. elongatus* are intermediate between *E. lindstroemi* and its descendant *E. elongatus*. This evolutionary development takes place in the upper part of the *P. anserinus* Zone and thus the *Eoplacognathus* present suggests a slightly younger age than the representatives of *Pygodus*. To conclude, the limestone is of Llandeilo (Middle Ordovician) age.".

Anderson (p. 21, 1968) considered the Ashland quarry rocks to be Silurian based on the presence of fossil fragments(?). Silurian rocks are exposed 500 m south-southwest of the quarry along an old woods road. The rock there is a slightly calcareous, coarse-grained sandstone of the Smyrna Mills Formation and contains fragmentary *Atrypa "reticularis"* and *Isorthis* which A.J. Boucot (G.S.C. fossil locality 85252, 1970) considers to be Late Llandovery to Pridoli in age. The substantial difference in age between the conodont-bearing limestone and the brachiopod-bearing sandstone clearly indicates the Silurian rocks unconformably overlie or are in fault contact with the Ordovician limestone at the quarry.

Another small inlier of Middle Ordovician limestone is exposed in the Markey Brook area about 3 km west of Craig Brook (St. Peter 1982*b*). A sample of the dark grey, stylolitic, nodular limestone from the south bank of Markey Brook at latitude 46°23'15"N and longitude 67°25'42"W yielded over 140 conodont specimens (locality 98624, Table 2 and Figure 10). Nowlan (1981*c*) writes of the assemblage: "The biostratigraphically most diagnostic species present in this sample is *Pygodus serrus* which is the nominal taxon of the *P. serrus* zone (Bergstrom 1971) and it indicates a Llanvirn (Middle Ordovician) age.".

The Middle Ordovician limestone and adjacent deformed quartzite and schistose felsic tuff at Markey Brook are unconformably overlain by limestone pebble conglomerate and sandy limestone. The limestone pebble conglomerate (locality 98626, latitude 46°23'17"N and longitude 67°25'47"W in Table 3) lies on the south bank of Markey Brook 160 m west of the Middle Ordovician limestone. Conodonts from the conglomerate suggest a Middle to Late Ordovician age (Nowlan 1981*c*). The sandy limestone (locality 98625 in Table 3), exposed 15 m east of the conglomerate contains a more diagnostic conodont taxa. According to Nowlan (1981*c*) "The presence of *Gamachignathus* in this sample is indicative of a Late Ordovician (Ashgill) age ... The occurrence of elements similar to *Protopanderodus varicostatus* and of elements of *Spinodus* are anomalous, because forms such as these are not known in strata younger than Middle Ordovician. This raises the possibility that this is a mixed fauna containing both Middle and Late Ordovician forms.". The presence of an angular unconformity between the sandy limestone and the adjacent Middle Ordovician limestone strongly supports the interpretation of faunal mixing.

The Craig Brook Limestone is thought to have been deposited in a relatively high energy shallow water environment. A shallow water site is implied from the highly diversified and prolific fauna. A high energy regime is indicated by the fragmentary condition of the brachiopods recovered by Bailey and Matthews (Bailey 1886), the presence of oolites, and disrupted algal mats. The latter suggests that, at least in part, the formation comprises an intertidal to shallow subtidal biofacies.

Exposures of Craig Brook Limestone on Mill Brook and Markey Brook to the West of I-18 map-area (discussed above) represent small inliers surrounded unconformably by Upper Ordovician limestone and Silurian Smyrna Mills rocks (St. Peter 1982*b*). The Craig Brook Limestone thus forms a Taconian basement to the Chaleur Bay Synclinorium. Fossiliferous rocks similar to the Craig Brook

TABLE 3.

Conodonts from Upper Ordovician limestone on Markey Brook.

Species \ Locality	98625	98626
Amorphognathus sp.	X	X
Belodina compressa (Branson & Mehl)	X	
Dapsilodus similaris (Rhodes)		X
Drepanoistodus sp.		X
D. suberectus (Branson & Mehl)	X	
Gamachignathus ensifer McCracken, Nowlan & Barnes	X	
G. hastatus McCracken, Nowlan & Barnes	X	
Icriodella sp.		X
I. superba (Rhodes) s.l.	X	
Panderodus gracilis (Branson & Mehl)	X	X
Periodon sp.	X	X
Protopanderodus liripipus Kennedy, Barnes & Uyeno		X
P. cf. *liripipus* Kennedy, Barnes & Uyeno	X	
Protopanderodus n. sp.		X
P. cf. *P. varicostatus* (Bergström & Sweet)	X	
Pseudooneotodus mitratus (Moskalenko)	X	X
Spinodus ramosus (Hadding)	X	
Walliserodus cf. *W. curvatus* (Branson, Mehl & Branson)	X	

Limestone are found within the Miramichi Anticlinorium about 30 km south-southeast of the above occurrences. There, limestone interbedded with greywacke, slate, and minor quartzite is late Llanvirn, *i.e.* early Middle Ordovician (Venugopal 1979). This suggests that within the report area, rocks of the Miramichi Anticlinorium extend under the Chaleur Bay Synclinorium from Little Clearwater Brook, where the nearest exposed rocks of the Anticlinorium are found, westward to at least as far as Mill Brook and Markey Brook where they are exposed as small inliers.

Rocks of similar age to that of the Craig Brook Limestone are exposed in the Aroostook-Matapedia Anticlinorium near Pat Brook about 130 km north of the report area where black chert contains graptolites most likely belonging to the *Nemagraptus gracilis* Zone of the late Llandeilo or early Caradoc age (Potter 1965; Rickards 1974).

UPPER ORDOVICIAN-LOWER SILURIAN

Carys Mills Formation (Unit OSs): The Carys Mills Formation is exposed in the core of a northeast-trending anticline in northwestern I-17 map-area and southwestern I-16 map-area. Regionally, the formation, along with correlated limestone of the Matapedia Group and Whitehead Formation extends from the Houlton area of central-eastern Maine to eastern Gaspe Penninsula, Quebec (Pavlides 1968; St. Peter 1978*b*; Skidmore 1965*a*, *b*; Ayrton 1967). In western New Brunswick the formation has been in past denoted as map-unit 4 on Geological Survey of Canada Maps 1190A and 1191A (Anderson 1968).

The total thickness of the Carys Mills Formation at Dry Brook in northwestern I-17 map-area can not be assessed since the basal beds of the succession are not exposed. The part that is exposed is greater than 200 m in thickness. At Woodstock, about 40 km to the southwest (Figure 1), the formation is greater than 750 m in thickness (Hamilton-Smith 1972).

The Carys Mills Formation at Dry Brook comprises thinly interbedded light grey, fine-grained, arenaceous limestone and dark grey calcareous slate. The limestone beds range from 1 to 4 cm in thickness, weather chalky buff to brown, and are rhythmically interbedded with slate. The slate typically contains parallel laminations of arenaceous limestone. Some slate beds have smeared wisps of graphite along well developed cleavage planes.

The Carys Mills Formation is conformably overlain by the Smyrna Mills Formation. The contact is not exposed in the report area but has been observed in the Woodstock area by Hamilton-Smith (1972). There, the contact is sharp and coincides with the uppermost characteristic limestone bed of the Carys Mills Formation. To the northwest, the Carys Mills Formation is underlain by Cambrian-Ordovician quartzite (Irrinki 1982) and Ordovician greywacke (Crouse 1982). In northern New Brunswick lithologically equivalent rocks of the Matapedia Group are conformably underlain by clastic turbidites of the Grog Brook Group (St. Peter 1978*b*).

The paleogeographic depositional site of the Carys Mills Formation has received little attention from the several geologists who have examined it. Typical Bouma structures in arenaceous limestone and slate in northern New Brunswick led St. Peter (1978) to suggest that the formation was deposited at bathyal or

abyssal depths in a marine basin. Recent work on numerous trace fossils from beds in northern New Brunswick suggest to Pickerill (1980) that the formation was deposited in relatively deep water, most likely on a basin slope.

No fossils were uncovered in the Dry Brook area during this survey. Graptolite localities are known in the Gaspe Peninsula (Lesperance 1968); in eastern Maine and western New Brunswick (Pavlides 1968); and in northern New Brunswick (Rickards and Riva 1981). These indicate that the formation ranges from the *Pleurograptus linearis* Zone (early Ashgill, Late Ordovician) to the *Monograptus gregarius* Zone (middle Llandovery, Early Silurian) according to the revisions of Rickards and Riva (1981).

SILURIAN

Smyrna Mills Formation: The name Smyrna Mills Formation was introduced by Pavlides and Berry (1966) in the Houlton area of eastern Maine to describe a Silurian sequence of interbedded siltstone, slate, sandstone, minor conglomerate and manganiferous ironstone. The name was subsequently extended to New Brunswick by Pavlides (1968) and Hamilton-Smith (1972).

The thickness of the Smyrna Mills Formation in southwestern I-16 map-area from the upper beds of the Carys Mills Formation to the base of the Lower Devonian Wapske Formation is estimated to be between 600 and 900 m. The sparce outcrop present in the area indicates the rocks are compressed into minor folds with wavelengths of several tens of metres. For this reason a definitive thickness can not be given. In the Woodstock area to the southwest (Figure 1), Hamilton-Smith (1972) estimates the exposed part of the Smyrna Mills Formation to be 1,700 to 2,000 m in thickness. Pavlides and Berry (1966) give a thickness of 1,800 m in the Houlton-Smyrna Mills area of Maine.

Within the Juniper-Knowlesville-Carlisle area, the Smyrna Mills Formation comprises mostly sedimentary rocks and minor mafic volcanic rocks.

Sedimentary Rocks (Unit Ss) include green and grey calcareous sandstone, green and grey siltstone, green slate; minor green nodular siltstone, red slate, graptolitic siltstone, lithic wacke, pebble conglomerate, quartzose sandstone, quartzose silt stone, limestone, and felsic volcanic rocks.

Green, fine-grained, calcareous sandstone is well exposed along Highway 107 between Argyle and Foreston in I-16 map-area and along North Becaguimec River about 0.5 km below Lower Howard Brook in I-18 map-area. The rock occurs in massive beds several metres thick and accounts for 30 to 40 per cent of the observed exposures in the formation. The massive character of the beds is seen from thin section to be the result of intensive bioturbation and homogenization. The sandstone consists of quartz, detrital muscovite, minor plagioclase and biotite in a matrix of white mica, chlorite, and calcite cement. In places, the sandstone beds contain crinoid ossicles and other pyritiferous shelly debris. The rock shows irregular to dendritic films of pyrolusite.

A unique outcrop of calcareous sandstone is exposed on the south bank of an unnamed tributary of Craig Brook in western

I-18 map-area at latitude 46°22'44" and longitude 67°23'56". The sandstone contains 10 per cent light grey crystalline limestone "ellipsoids" 1 to 20 cm in length. The ellipsoids consist of broken crinoid debris, corals, bryozoans, and conodonts (see below). The outcrop also has well preserved tabulate corals and solitary crinoids that appear to be in growth position.

Grey calcareous sandstone is exposed along the small tributaries of Coldstream south of Garvey Mountain in northwestern I-17 map-area. The rock is brown-weathering, medium grey, fine- to medium-grained and occurs in beds ranging from 2 to 10 cm in thickness. The beds are commonly graded and display parallel laminations and small scale cross-laminations. The sandstone consists of abundant quartz, minor feldspar, detrital muscovite, and biotite in a very fine-grained matrix of white mica, chlorite and calcite. The sandstone is rhythmically interbedded with parallel-laminated dark grey siltstone.

Green siltstone is an abundant lithotype of the Smyrna Mills Formation. It is exposed along North Becaguimec River about 1 km below the mouth of Lower Howard Brook in I-18 map-area and in numerous small outcrops near Hamilton Brook in I-17 map-area. The siltstone occurs in beds several metres thick. Most of the thick siltstone sections contain very few thin interbeds of fine-grained sandstone.

Green slate, an abundant rock type of the Smyrna Mills Formation, is best exposed along the headwaters of Cold Stream and Hemphill Brook in I-17 map-area. The slate contains rusty parallel laminations of siltstone and occurs in beds several metres in thickness. The rock consists of about 20 per cent quartz, muscovite, and plagioclase silt in a calcareous matrix of clay-size white mica, chlorite and minor opaque dust.

Green nodular siltstone is locally associated with the green slate. A readily accessible exposure occurs along the secondary highway 2 km north of East Knowlesville in I-17 map-area. The siltstone weathers light brown, is slightly calcareous, and contains irregular ellipsoidal to sausage-shaped light grey lithographic limestone nodules ranging from 0.2 mm to 4 cm in length. The percentage of nodules varies from bed to bed, ranging from 5 to 70 per cent. In the densely nodular beds, the nodules commonly coalesce forming a compact nodular limestone (Figure 12). Some of the nodules contain shelly debris and crinoid fragments (Figure 13).

In addition to limestone nodules, the green siltstone along North Becaguimec River, in places, contains a few nodules of light brown-weathering, slightly calcareous chert. The chert nodules are typically larger than the limestone nodules but apparently formed by a similar process. A diagenetic origin is indicated by the compactional draping of the enclosing siltstone over the nodules (Figure 14).

Red slate occurs locally along Hamilton Brook and east of Lower Howard Brook in I-17 map-area. A few beds are exposed along North Becaguimec River adjacent to graptolite locality 96940 and about 150 m southwest of graptolite locality 96941. The beds along the river range from 1 to 15 m in thickness and are interbedded with green slate, nodular siltstone and limestone.

Figure 12. Nodular siltstone, coalescing nodules form a bed of nodular limestone below the lens cap.

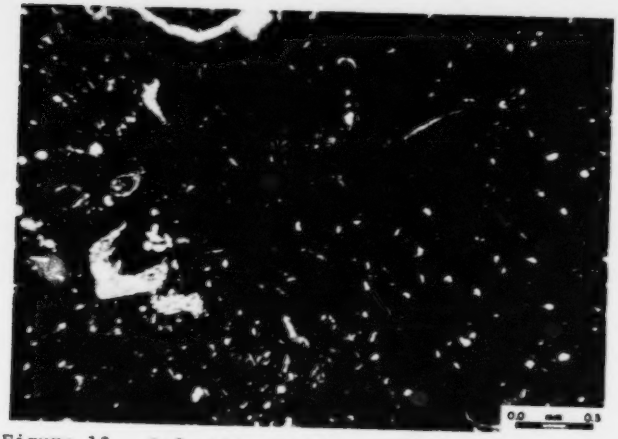


Figure 13. Infantile shelly debris in nodular limestone.

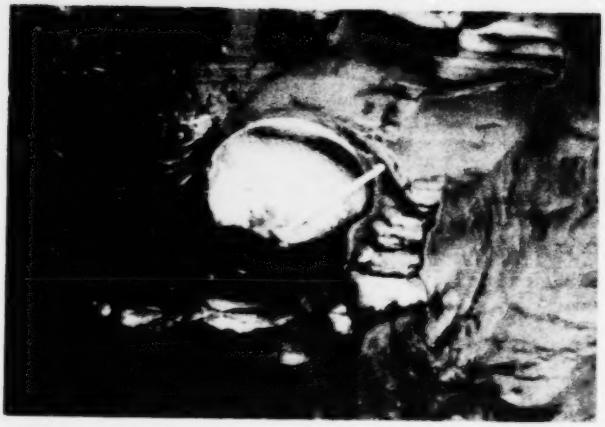


Figure 14. Diagenetic chert nodule with compactional draping of enclosing siltstone due to loading.

Dark grey, rhythmically parallel-laminated, graptolitic siltstone is a distinctive minor lithotype of the Smyrna Mills Formation (Figure 15). Exposures are seen 225 and 350 m below the mouth of Lower Howard Brook at fossil localities 96939 and 96940 in I-18 map-area. The graptolitic beds range from 1 to 15 m in thickness and are interstratified with calcareous sandstone, green slate, and nodular siltstone. The graptolitic siltstone comprises about 60 per cent silt grains of quartz, detrital muscovite, plagioclase, accessory biotite and carbonaceous matter in a matrix of white mica, chlorite, and microcrystalline calcite. The rock has very thin parallel laminations of light brown-weathering micrite that contains 5 per cent quartz silt and 3 per cent euhedral pyrite. The beds split into thin flaggy plates along the parallel laminations, in places, revealing well preserved monograptids.

Grey lithic wacke occurs locally in the Smyrna Mills Formation (see "lw" symbol on Plates 80-35A, 80-36A, and 80-37A). The lithic wacke weathers light brown, varies from medium-grained to granular, and occurs in beds ranging from 10 cm to 1 m in thickness. The rock consists of poorly sorted clasts of quartz, feldspar porphyry, massive felsite, quartz-muscovite schist, minor feldspar, mafic volcanic rock, gabbro, and granite in a matrix of silt-size quartz, mica, chlorite and calcite. In places, the lithic wacke contains intraformational siltstone clasts 0.5 to 8 cm in length.

Polymictic conglomerate ("cgl" symbol on accompanying Plates 80-35A and 80-36A) is associated with the grey lithic wacke. The conglomerate occurs in brown-weathering, very thick beds containing up to 80 per cent, poorly sorted granules and pebbles of mafic and felsic volcanic rocks, quartz, fine-grained quartzose arenite, and intraformational slate. The clasts are set in a very fine-grained sandstone matrix. The conglomerate is typically pervasively cleaved.

Figure 15. Parallel-laminated graptolitic siltstone.

Green, hard quartzose sandstone occurs in a few exposures along Cold Stream in western I-17 map-area (see "qa" symbol on Plate 80-36A). The rock is interstratified with green siltstone and minor lithic wacke.

Quartzose siltstone is seen in a few exposures near South Knowlesville in I-17 map-area and north of Craig Brook in I-18 map-area. The rock is calcareous and occurs in massive thick beds characterized by deep, orange, spheroidal weathering. On fresh surfaces the rock is mottled light and dark grey suggesting that extensive bioturbation has taken place.

Limestone is a characteristic minor rock type of the Smyrna Mills Formation (see "ls" symbol on Plate 80-37A). Exposures can be seen at an abandoned quarry north of Highway 575, and at nearby fossil locality 97518. The limestone is light grey, light brown-weathering, massive, and thickly bedded. The rock is a very clean carbonate consisting of partially recrystallized microspar intraclasts (0.1 to 0.7 mm) in a blocky spar cement. The limestone is commonly transected by a reticulate network of calcite veins and unlike the Ordovician Craig Brook Limestone is not carbonaceous or stylolitic. Regionally, the limestone is seen to lie in the uppermost part of the Smyrna Mills Formation (St. Peter 1982*a*, *b*).

A flow of green felsic volcanic rock occurs about 150 m below the base of the Wapske Formation 800 m east of Lower Howard Brook in southwest I-17 map-area (see "fv" symbol on Plate 80-36A). The flow is 2 m in width; it is overlain by red and green slate and underlain by fine-grained calcareous sandstone. The small feldspar crystals in the quartzofeldspathic groundmass exhibit a marked flow alignment and are replaced by sericite. Phenocrysts of plagioclase making up 10 to 15 per cent of the rock are pseudomorphously replaced by calcite. Sparse mafic phenocrysts are

replaced by intergrown epidote, sphene, and opaque mineral(s). Disseminated pyrite is partially replaced by hematite and limonite.

Mafic volcanic rocks (Unit Smv) are exposed in northwestern I-18 map-area along Craig Brook. West of fossil locality 97517 on Craig Brook, the mafic volcanic layer shown in I-18 map-area is separated from another volcanic flow by an intervening septum of green, crinoid-bearing, calcareous sandstone. The presence of this characteristic Smyrna Mills sandstone lying between the volcanic flows attests to the Silurian age of the latter rocks.

The mafic volcanic rocks are dark greyish green and vary from massive to densely amygdaloidal. The amygdaloidal rock contains up to 25 per cent chlorite- and calcite-filled vesicles ranging from less than 1 mm to greater than 15 mm in diameter.

The contact between the Smyrna Mills Formation and the Lower Devonian Wapske Formation is, in many places, marked by faults. The undisturbed contact has not been seen in the report-area. Small exposures along the ditch of the road leading west from Hamphill Corner in I-17 map-area suggest the formations are conformable. The contact is poorly exposed about 1 km west of I-18 map-area at the first sharp turn in the road leading south from Windsor (St. Peter 1982b). There massive lithic wacke and overlying orange-weathering, mottled calcareous siltstone of the Smyrna Mills Formation are overlain by thinly interbedded plant-bearing sandstone and dark grey siltstone of the Wapske Formation. At the contact, both formations strike south 10° east and dip 80° west.

The absence of well exposed undeformed sections and the lack of time to examine the formation in detail presently prohibits a full understanding of the facies relationships and environment of deposition of the Smyrna Mills Formation. The formation is dominated by fine-grained clastic and carbonate rocks. The lack of current or wave-generated traction structures indicates the rocks were deposited in a relatively quiet low energy environment. Moderately well preserved graptolites in the siltstone beds also point to a low energy regime. The highly bioturbated green calcareous sandstone locally containing solitary corals in growth position suggests a low rate of sedimentation.

Limestone nodules, similar to those in the siltstone and limestone, have been described in the LaVieille Formation of northern New Brunswick as having formed diagenetically in moderate water depth (Noble and Howells 1974) possibly on the outer shelf where sedimentation rates were low, yet sufficient to restrict the formation of limy hard grounds.

The red manganiferous-hematitic slates and associated ironstones in the Smyrna Mills Formation to the west of the area have been interpreted by Anderson (1968) as a shallow water facies deposited a considerable distance from shore. This is in agreement with modern interpretations of oolitic ironstones (Dimroth 1979). The Smyrna Mills ironstones are locally oolitic, and are associated with lithotypes similar to those of the Silurian Clinton ironstones of the southern Appalachians (see for example, Stanton 1972).

To conclude, the general fine-grained aspect of the formation, together with the textures and structures of the limestone

TABLE 4.

Graptolites from Smyrna Mills Formation

Species \ Locality	96937	96939	96940	96941	96952
Bohemograptus bohemicus	X				
Monograptus flemingi			X		
Monograptus cf. *scanicus*				X	
Pristiograptus ex. gr. *dubius*	X				X
Pristiograptus sp. or *Saetograptus* sp.	X				
Pristiograptus cf. *dubius*		X			
Pristiograptus cf. *tumescens*				X	
P. cf. *vicinus* or *P.* cf. *Pseudodubius*			X		
Monoclimacis ex. gr. *vomerinus*			X		
Saetograptus colonus compactus		X		X	X

Comments from A. Lenz:

96937 - Not certain if *B. bohemicus* is *B. bohemicus bohemicus* (typically lower Ludlow) or *B. bohemicus tenuis* (most commonly middle Ludlow)

96939 - Early Ludlow, *nilssoni* Zone

96940 - Late, but not latest, Wenlock, probably *lundgreni testis* Zone

96941 - Early Ludlow, *nilssoni* Zone

96952 - Early Ludlow, *nilssoni* Zone

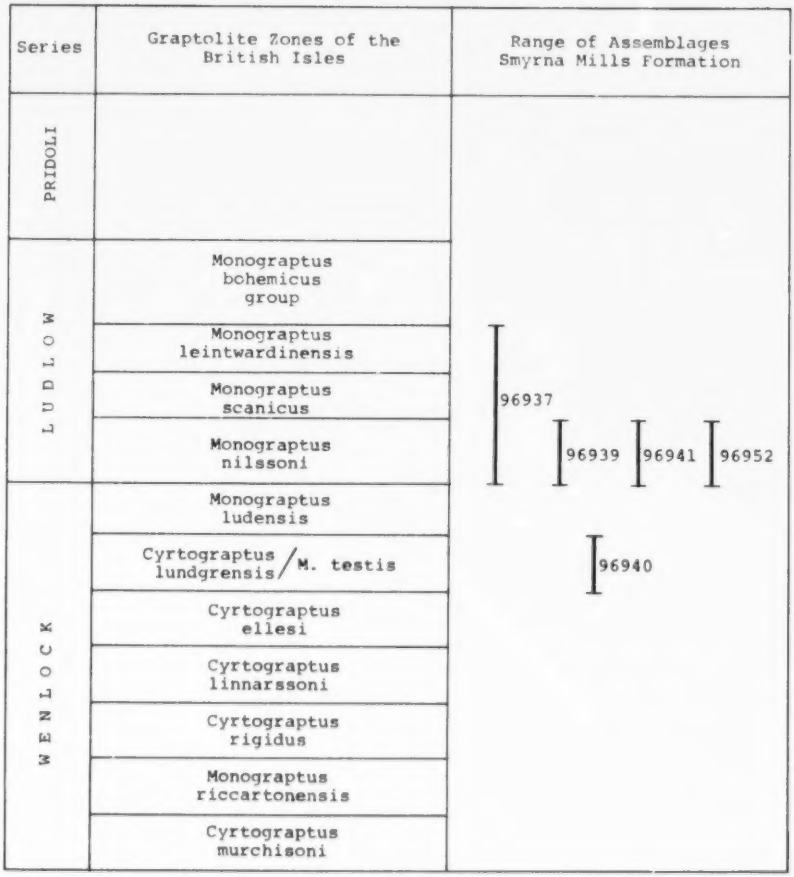


Figure 16. Silurian graptolite zones (after Berry and Boucot 1970)

and ironstone suggest the rocks were largely deposited below wave base in an outer shelf environment. This fits reasonably well with the postulated position of the Miramichi land area to the east during Wenlock-Ludlow time (Boucot 1968). Assuming considerable shortening of the Silurian-Devonian section by folding and faulting, the Smyrna Mills Formation in the report area was probably deposited substantially less than 100 km from the Silurian strand line.

The age of the graptolite-bearing Smyrna Mills Formation in the Houlton-Smyrna Mills area of eastern Maine has been well documented by Pavlides and Berry (1966) as late Lower Llandovery to Lower Ludlow.

In the North Becaguimec River-Howard Brook area of I-17 and I-18 map-areas graptolite assemblages at five new localities range in age from late Wenlock to early or possibly middle Ludlow (Table 4 and Figure 16). The fauna were identified by Alfred Lenz (*written communication* to M.J. Copeland 1980); his comments are given in Table 4.

Fossil locality 28546 on the west side of North Becaguimec River 300 m southwest of the mouth of Craig Brook is from a collection made by L.M. Cumming in 1956. A single graptolite specimen, *Monograptus scanicus* Tullberg, was collected and according to T.E. Bolten (*personal communication* 1981) it indicates a Lower Ludlow age.

Calcareous siltstone at fossil locality 96936 in southwestern I-17 map-area contains platyceratid snails that suggest a Silurian or Lower Devonian age (A.J. Boucot *written communication* 1980). Similar gastropods associated with the trilobite *Cheirurus* and some long-ranging conodonts occur in probable Silurian limestone 12 km west-northwest of Carlisle (Pavlides 1968).

Excellently preserved *Favosites* sp. cf. *F. forbesi* (Milne-Edwards and Haime) occur in growth position in a bed of limy sandstone at locality 97517 on a tributary of Craig Brook in western I-18 map-area. Bolton (1980) describes the coral as "a widespread Silurian species throughout Europe and eastern Canada".

The coral-bearing beds at locality 97517 contain scattered light grey crystalline limestone "ellipsoids" (see above). Several of these ellipsoids were digested yielding 45 moderately well preserved conodonts, identified by Godfrey S. Nowlan (1981a) as *Belodella silurica* (Barrick), *Dapsilodus obliquicostatus* (Branson and Mehl), *Decoriconus* sp., *Ozarkodina excavata excavata* (Branson and Mehl), *Ozarkodina sagitta* (Walliser), and *Ozarkodina* sp.. "*Ozarkodina excavata* ranges throughout most of the Silurian, but *O. sagitta* is known only from the Wenlock. The elements referred to *O. sagitta* herein most closely resembles *O. sagitta rhenana* (Walliser), but more material is required for positive identification. Thus the sample is of Wenlock, possibly early Wenlock age".

An exposure of limestone, about 50 m east of the more southerly of the two limestone quarries in western I-18 map-area, was sampled for conodonts. Fragments of *Panderodus* recovered from the sample (fossil locality 97518) give an imprecise age of middle Ordovician to at least the end of the Silurian (Godfrey S. Nowlan *written communication* 1980). The limestone is like that

exposed to the north in the old Henderson limestone quarry at Windsor. The Windsor quarry lies 250 m west of I-18 map-area, just north of the highway leading west from Armond. Bailey (p. 17G, 1886) reports the discovery of *Dalmanites*, *Pentamerus galeatus*, *Atrypa reticularis*, and *Strophomena depressa* from the limestone at or near the quarry. He assigned a Silurian age to the assemblage.

LOWER DEVONIAN

The Lower Devonian Tobique Group sedimentary and volcanic rocks that overlie the Smyrna Mills Formation were divided into the Costigan Mountain Formation and Wapske Formation by St. Peter (1978*a*). The Tobique Group is continuously exposed within the Chaleur Bay Synclinorium from Juniper to Serpentine River more than 80 km to the north. Lithologically similar Lower Devonian (Helderberg) sedimentary and volcanic rocks - Scott Siding Slate, Dorrington Hill Formation, Hartin Formation - are confined to a graben that transects the Miramichi Anticlinorium from Cloverdale in I-18 map-area to Canterbury 45 km to the south (Figure 1).

Costigan Mountain Formation: The Costigan Mountain Formation comprises predominantly felsic volcanic rocks subordinate sedimentary rocks, and minor mafic volcanics. The formation is exposed in the eastern part of the map-area, from Juniper in the north to North Becaguimec River in the south (Figure 2).

The thickness of the Costigan Mountain Formation is difficult to estimate in the map-area. The eastern part of the formation is intruded by the Becaguimec Lake Gabbro; the western part is in fault contact with the Wapske Formation and unconformably overlain by the Carlisle Formation. If it is assumed that the west-dipping bedding readings are representative of the attitude of the unexposed beds, and that the section is not repeated by faults, then the section along Pokiok Brook in I-18 map-area is about 3 km in thickness.

Felsic volcanic rocks (Unit Dfv) of the Costigan Mountain Formation comprise pink feldspar porphyry, pink quartz-feldspar porphyry, pink lapilli tuff, and minor eutaxitic rhyolitic tuff.

Pink feldspar porphyry, the most abundant rock-type in the unit, contains 1 to 8 per cent plagioclase (oligoclase) phenocrysts ranging from 1 to 3 mm in length. The phenocrysts are set in a subtrachytic microcrystalline, quartzofeldspathic matrix marked by flow-aligned feldspar microlites (Figure 17). Where the porphyry is intruded by gabbro and granite the rock is hornfelsic and the subtrachytic texture is accentuated by metamorphic biotite and chlorite.

Pink quartz-feldspar porphyry is closely associated with the feldspar porphyry. The rock contains 1 to 3 per cent anhedral and embayed quartz phenocrysts commonly occurring in clusters forming a glomeroporphyritic texture. The phenocrysts of plagioclase (oligoclase) range from 0.5 to 5 mm in length and comprise 1 to 5 per cent of the rock. The phenocrysts are set in either a subtrachytic or equigranular massive matrix. The subtrachytic texture is defined by elongate stringers of quartz and

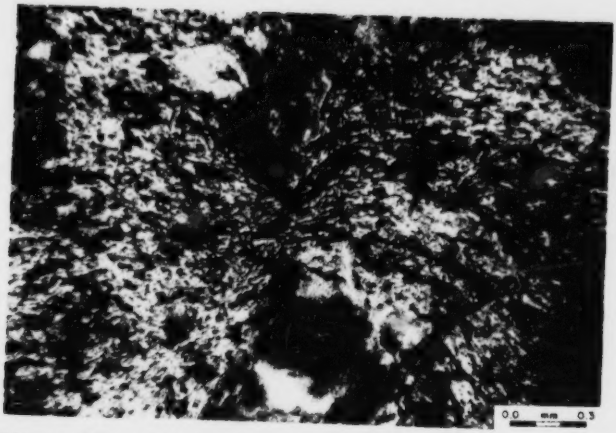


Figure 17. Feldspar porphyry with flow-aligned matrix of feldspar microlites and opaque minerals.

subparallel secondary sericite. The massive quartz-feldspar porphyry may in part represent hypabyssal intrusions.

Pink lapilli tuff is exposed along the west tributary of Pokiok Brook and west of the mouth of Pokiok Brook along North Becaguimec River in I-18 map-area. The rock contains 2 to 3 per cent quartz phenocrysts, 10 to 15 per cent plagioclase phenocrysts, 0 to 1 per cent biotite phenocrysts, and 5 to 20 per cent autolithic lapilli in an equigranular or flow-aligned matrix of quartz, feldspar, and secondary sericite, chlorite, epidote, and hematite. The quartz phenocrysts are typically embayed and some are broken. The plagioclase phenocrysts locally tend to form glomeroporphyritic clusters. Biotite is largely replaced by chlorite and opaque minerals. The autolithic lapilli of quartz-feldspar porphyry range from 2 to 20 mm in diameter. They are best seen on weathered outcrops where subtle differences in color and/or texture distinguishes them from the matrix.

A distinctive outcrop of rhyolitic lapilli tuff occurs on the southwest slope of the hill east of Tamarac Brook in I-17 map-area. Similar rock occurs as a narrow layer in the sedimentary rocks of map-unit Ds_1 along the north part of Pokiok Brook in I-18 map-area. The rock at both localities contains more than 40 per cent lapilli and blocks of subtrachytic plagioclase porphyry locally up to 30 cm in length. In addition, the rock at Tamarac Brook contains minor clasts of siltstone and mafic volcanic rock. The matrix of the tuff consists of microcrystalline quartz and feldspar, and minor sphene, chlorite, epidote, and carbonate.

Pink- to buff-weathering, layered rhyolitic tuff occurs locally. An exposure of this rock-type is seen on the east bank of North Becaguimec River 850 m south of the mouth of MacIntosh

Brook in I-18 map-area. The rock is distinguished by alternating light and dark colored eutaxitic layers. The light colored layers are seen from thin section to be devitrified glass lenses comprising microcrystalline quartz and feldspar (Figure 18). The rock, in places, contains lapilli of pilotaxitic felsite, massive aphanitic felsite, and minor spherulitic rhyolite.

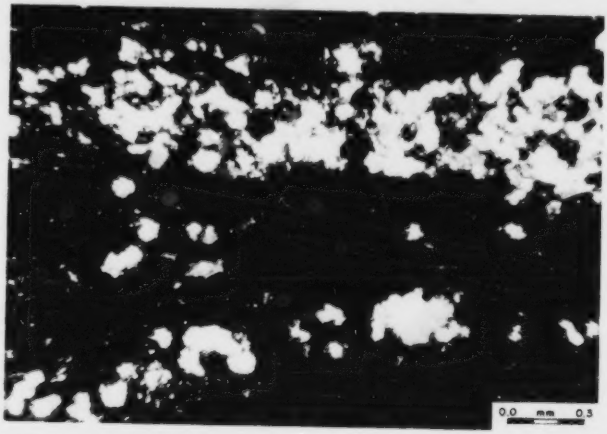


Figure 18. Devitrified eutaxitic texture of rhyolitic tuff.

Sedimentary rocks (Unit Ds) of the Costigan Mountain Formation comprise an interbedded sequence of siltstone, quartzose sandstone, and minor polymictic conglomerate. The sedimentary rocks in southeastern I-16 map-area and northeastern I-17 map-area are cut by dykes of gabbro and granodiorite.

The sedimentary sequence in southeastern I-16 and northeastern I-17 map-areas comprises mostly dark grey, parallel-laminated siltstone with only minor thin interbeds of light grey, quartzose sandstone. The rocks are hornfelsic. The siltstone consists of quartz (25 per cent), reddish brown biotite (50 to 60 per cent), and minor chlorite, muscovite, and plagioclase. The siltstone exposures near granodiorite commonly contain poikiloblasts of potash feldspar and accessory tourmaline. The sandstone interbeds contain 65 to 80 per cent quartz, 15 to 25 per cent biotite, and minor oligoclase, and epidote. Actinolite is, in places associated with the biotite.

The sedimentary sequence in I-18 map-area, unlike that described above, is mostly composed of thin to thick beds of quartzose sandstone interstratified with thin subsidiary beds of dark grey siltstone (Figure 19). The sandstone comprises 50 to 90 per cent of most outcrops. It is light grey, fine- to medium-grained, and massive. Some beds show faint parallel laminations and others display ripple cross laminations. The sandstone contains about 40 per cent quartz, 15 per cent felsic rock fragments, 4 per cent feldspar, accessory sphene, rutile and opaque minerals set in a microcrystalline matrix of white mica, chlorite, epidote, and quartz.

Figure 19. Interstratified thin to thick beds of quartzose sandstone with thin partings of more deeply weathered siltstone.

An outcrop of polymictic conglomerate is exposed on the west bank of Pokiok Brook in northern I-18 map-area (see "cg" symbol on Plate 80-37A). The rock consists of about 50 per cent moderately well-rounded granules, pebbles, and a few cobbles in a very fine-grained quartzose matrix. In the lower part of the outcrop, near the stream bed, most of the pebbles are trachytic felsite and feldspar porphyry. In the upper part of the outcrop the pebbles are mostly quartzose sandstone and dark grey siltstone. All the pebbles are similar to the Costigan Mountain lithotypes described above, and are believed to be intraformational.

Mafic volcanic rocks (Unit Dmv_1) of the Costigan Mountain Formation occur in three layers in I-18 map-area. The first, a north-trending layer, is exposed on MacIntosh Brook and the next unnamed brook 500 m to the north. The second, a narrower layer, is exposed on Pokiok Brook about 800 m north of North Becaguimec River. The third layer occurs east of Pokiok Brook about 1.5 km northeast of the second layer. The third layer has not been seen in outcrop, but has been intersected in two drill holes put down by Atlantic Coast Copper and J.D. Irving Limited in 1974 (see below under Economic Geology). The mafic volcanic rocks are dark green and contain vesicles filled with calcite, chlorite, and minor epidote.

At MacIntosh Brook the mafic volcanic rocks contain a few interbeds of sedimentary rocks similar to those described above under Unit Ds_1). The eastern contact between mafic volcanic rocks and one of the sedimentary interbeds is seen to be conformable and steeply dipping (Figure 20). This serves to separate these rocks from the subhorizontally disposed Carboniferous mafic volcanic rocks on Lake Brook 2.5 km to the south.

The contact between the Costigan Mountain Formation and

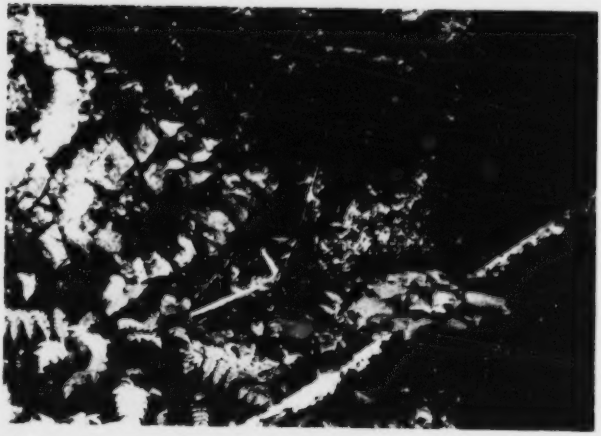


Figure 20. Mafic volcanic rocks of the Costigan Mountain Formation (left) conformably underlain by siltstone (right)

Wapske Formation is marked by a cataclastic zone. This is best seen in the rocks along North Becaguimec River 600 m east of the mouth of Little Pokiok Brook. On the south bank of the river, cataclastic rhyolite is overlain unconformably by Carboniferous conglomerate.

The subaerial nature of the felsic volcanics of the Costigan Mountain Formation is evident from the presence of welded eutaxitic ash flow tuffs at several horizons within the formation. The sedimentary rocks have not been examined in sufficient detail to adequately interpret their environment of deposition. Trace fossils - among them, identifiable *Helminthopsis* sp. and *Planolites* sp. - on the surface of quartzose sandstone beds exposed along the large eastern tributary of Pokiok Brook indicate the sedimentary rocks are marine (Pickerill *personal communication* 1980). Carbonized plant fragments on flaggy quartzose sandstone beds along Pokiok Brook are tentatively taken to indicate the rocks were deposited, perhaps in shallow water, adjacent to a land area that supplied plant debris.

No dateable fossils were found in the Costigan Mountain Formation during this survey. Plant fragments in the sandstone beds at fossil locality 96945 clearly show the rocks are not Cambro-Ordovician as mapped by Anderson (1968). The formation is correlated with lithologically similar Lower Devonian (probably Helderberg) rocks to the northeast (St. Peter 1978*a*, 1981).

Wapske Formation: The Wapske Formation underlies most of the western part of the report area. The thickness of the formation is difficult to determine since the rocks are folded and transected by faults. The section in the fault block between Foreston and the headwaters of Elder Brook in I-16 map-area is about 4 km thick assuming the section is not repeated by faults.

The formation is divided into a unit of sedimentary rocks, and a unit of mafic volcanic rocks.

Sedimentary rocks (Unit Dsg) comprise slate, siltstone, sandstone, and conglomerate.

Slate is the most abundant rock-type in northwestern I-16 map-area. A section several hundred metres in thickness is exposed along Teague Brook. To the west, at Shikatehawk River, the slate is interbedded with sandstone. The slate is dark grey and consists of about 5 per cent quartz silt in a microscopic matrix of sericite, chlorite and opaque minerals. Locally, the rock contains porphyroblasts of chlorite that pre-date a well developed slaty cleavage (Figure 21). The slate is characterized by parallel laminations of light brown-weathering, medium grey, very fine-grained sandstone or siltstone. The laminations consist of abundant quartz and sericite, minor chlorite and calcite, and accessory feldspar, sphene, and opaque minerals.

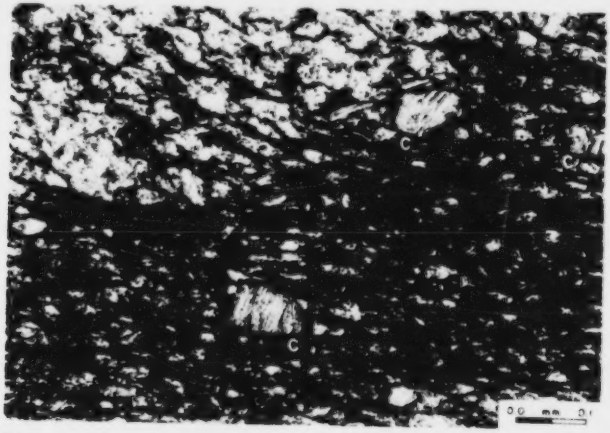


Figure 21. Porphyroblasts of chlorite (c) in dark grey slate. Transposed siltstone lamination in upper left.

Siltstone, the second-most abundant rock-type of the unit, occurs as thin to very thick beds interstratified with sandstone. The siltstone is well exposed along Upper Howard Brook and the road leading south from South Knowlesville in I-17 map-area. The rock is dark grey and comprises quartz, detrital muscovite, and minor feldspar set in a matrix of white mica, chlorite, and minor carbonate. Bedding is shown by parallel laminations of fine- to very fine-grained sandstone. The laminations are, in places, graded or internally ripple cross-laminated. The rock is characterized by a poorly developed cleavage and a peculiar subconchoidal fracture habit in which the separated fragments fit together like saucers.

Sandstones and conglomerates intercalated with the slate and siltstone are classified according to the simplified scheme

shown in Figure 22. Wackes are those rocks with greater than 15 per cent matrix. Compositions were estimated visually from thin sections. The percentage of clasts are undoubtedly biased where such a small field of view is examined in the conglomerates. In addition to quartz, clasts of quartzite, quartzose arenite, felsite and chert were included with the quartz apex of Figure 22. The sandstones in the area are quartzose arenites, quartzose wackes and lithic arenites.

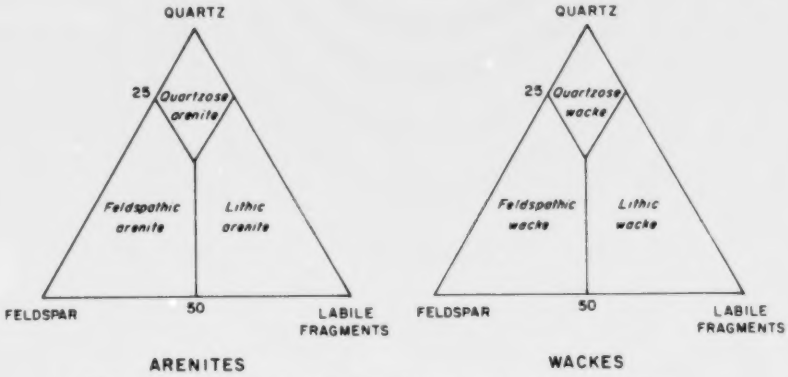


Figure 22. Simplified sandstone classification (after Blackburn *et al.* 1978).

Fine-grained quartz arenite is exposed southeast of Biggar Ridge in I-16 map-area, along Lower Howard, Upper Howard, and Hamphill Brooks in I-17 map-area. The quartzose arenite occurs in light brown-weathering, light grey beds ranging from 2 to 40 cm in thickness. The beds are parallel-laminated, locally cross-laminated, and interstratified with thin beds of dark grey siltstone (Figure 23). The quartzose arenite southeast of Biggar Ridge is hornfelsic and contains metamorphic biotite. The rock in I-17 map-area commonly occurs in flaggy beds bearing plant debris. At Lower Howard Brook, the quartzose arenite is moderately calcareous; the quartz grains are set in a microsparry calcite cement.

Medium- to coarse-grained quartzose wacke is best seen along Shikatehawk River in I-16 map-area and along the various tributaries of Cold Stream in I-17 map-area. The rock occurs in beds ranging from 10 cm to greater than 3 m in thickness. The beds are interstratified with slate, siltstone, and locally quartzose arenite and conglomerate. The quartzose wacke beds are either massive or normally graded and overlie finer grained interbeds with either sharp or erosional contact. The base of beds overlying erosional contacts contain conspicuous intraformational slate fragments. In an exposure along the brook immediately south of East Glassville in I-16 map-area, a quartzose wacke bed contains slate fragments up to 20 cm in length and 3 cm in width.

Figure 23. Parallel interbedded fine-grained quartzose arenite and dark grey siltstone.

The quartzose wacke contains less quartz and more feldspar and labile fragments than the associated quartzose arenite and more feldspar but less labile clasts than the associated beds of conglomerate. The labile clasts in the wacke constitute about 10 per cent of the rock and include muscovite schist, felsic volcanics, minor diabase, detrital muscovite and biotite. The muscovite schist fragments have a well developed cleavage that predates the cleavage in the rock. The sand grains are enclosed in a matrix of sericite, chlorite, and microscopic quartzose silt.

Lithic arenite is found associated with conglomerate, in western I-18 map-area on Day Brook, on the North Becaguimec River (Figure 24) and its eastern tributaries north of Carlisle, and south of Northville. The lithic arenite is dark grey and varies from medium- to very coarse-grained. The finer grained rock commonly splits into flaggy slabs revealing highly carbonized plant fragments. This is particularly apparent in the beds along the east tributary of Day Brook (Figure 25). The sandstone occurs in thin to thick beds, some of which are normally graded. In most outcrops the sandstone forms interbeds with parallel upper and lower contacts. However, an outcrop along a small brook on the east side of North Becaguimec River immediately south of fossil locality 96953 shows a different bedform. The sandstone there is in lenticular beds 4 to 5 m in length and 30 to 40 cm in thickness. The overlying conglomerate has eroded into the sandstone forming cut and fill structures.

The sandstone is grain supported and mostly consists of well sorted and rounded lithic clasts. The interstitial sites around the clasts are filled with sericite, chlorite, quartz, and hematite. The clast content of the rock is similar to that of the associated conglomerate (see p. 42).

Conglomerate is found as a minor lithotype sporadically

Figure 24. Thick-bedded lithic arenite on North Becaguimec River 300 m east of the mouth of Upper Howard Brook.

Figure 25. Interbedded flaggy lithic arenite (centre) and conglomerate (upper left and lower right) on Day Brook.

distributed throughout the Devonian section, in I-16, I-17 and northwestern I-18 map-areas. The conglomerate occurs as massive beds locally attaining thicknesses of about 5 m. It is typically associated with, and commonly grades into, beds of quartzose wacke.

The lithic clasts within the conglomerate are well rounded, but poorly sorted (Figure 26). They range in size from medium-grained sand to 15 cm cobbles. Exceptionally large boulders - up to 1 m in length - are present in a bed exposed on Lower Howard Brook east of the Knowlesville Fault adjacent to the mafic volcanic rocks of map-unit Dmv_2 in I-17 map-area. The lithic clasts - in addition to quartz - include a multitude of rock types; among them are abundant felsic and mafic volcanics, diabase, quartzose arenite and slate. Some beds also contain pebbles of sericite schist, quartzite, black chert, blue-green chert, quartzose wacke, calcareous sandstone argillite, limestone and fossiliferous limestone (Figures 26 to 28). The clasts are enclosed in a muddy or silty matrix constituting between 15 and 50 per cent of the rock. The matrix comprises quartz, sericite, chlorite, sparry calcite, and accessory biotite, tourmaline, zircon, and opaque minerals. The rock is a lithic wacke according to the classification of Figure 22.

Figure 26. Poorly sorted, well-rounded pebbles in polymictic conglomerate north of Craig Brook.

The pebbles in the conglomerate are closely comparable to rock types of adjacent formations. For example, the felsic volcanic pebbles are indistinguishable from felsites of the Costigan Mountain Formation. The quartzose arenite, slate, quartzose wacke, and mafic volcanic clasts are believed to be largely intraformational. The quartzite, sericite schist, and black chert are similar to Cambrian-Ordovician rocks of the Miramichi Anticlinorium. The blue-green chert is anomalous. The limestone pebbles are undoubtedly derived from the Silurian Smyrna Mills Formation (*cf.* Figure 13 and Figure 29).

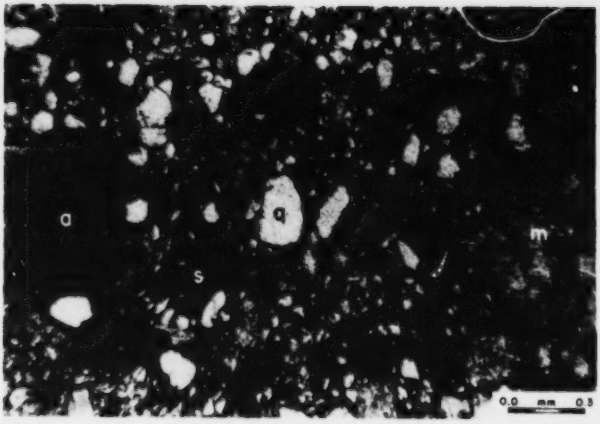


Figure 27. Poorly sorted conglomerate showing clasts of argillite (a), quartz (q), slate (s), and mafic volcanic rock (m).

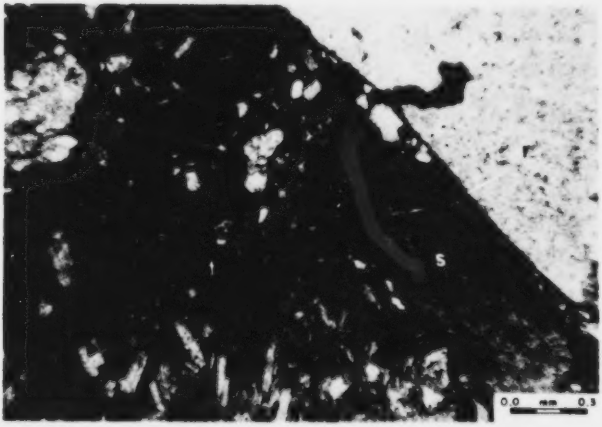


Figure 28. Conglomerate containing pebbles of trachytic rhyolite (t), sericite schist (s), and microcrystalline rhyolite (r).

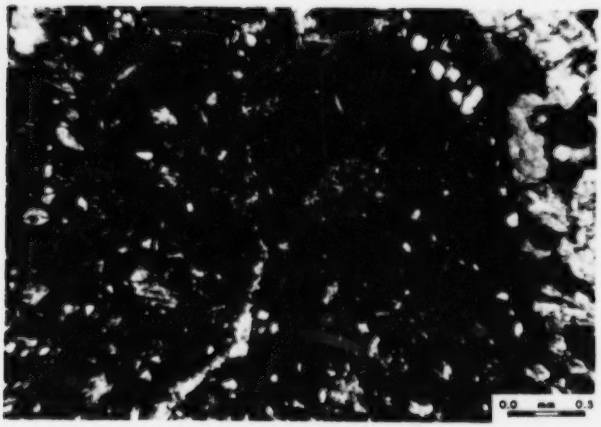


Figure 29. Conglomerate with pebbles of fossiliferous limestone.

Conglomerate is a major lithotype interstratified with sandstone in southern I-18 map-area north and south of Carlisle and along Day Brook. The exposed conglomerate and associated sandstone in this area are texturally mature lithic arenites rather than wackes in contrast to those farther north.

The conglomerate occurs in grey, brown-weathering, massive beds ranging from 1 m to greater than 5 m in thickness. The rock consists of about 90 per cent well rounded, but poorly sorted granules, pebbles, and minor cobbles in a sandy micaceous matrix. The long axes of the clasts are generally parallel to bedding surfaces. The clasts include abundant quartz, felsic volcanic rocks, slate, quartzose wacke and sericite schist (Figures 30 to 32). There are also clasts of granite, diabase, mafic volcanic rocks, siltstone, conglomerate, and red, black, and blue-green chert. Sand-size grains of plagioclase, muscovite, and biotite are common.

The Devonian rocks of southern I-18 map-area appear to represent a proximal conglomerate facies that interfingers with finer grained rocks to the north. Dated brachiopod assemblages and the presence of similar plant-bearing sandstones from both units strongly support this interpretation.

As briefly mentioned above under the Smyrna Mills Formation, the presence of Smyrna Mills limestone pebbles in the Wapske Formation conglomerates points to the presence of an erosional hiatus between the two formations. The erosional break which is marked by the absence of latest Silurian (Pridoli) to earliest Lower Devonian (lower Gedinne) fauna has been documented at several localities in the northern Appalachians and referred to as the Salinic disturbance (Boucot 1962). However, within the report area, uplift was post latest Silurian as Pridoli fauna occur immediately to the south of the area (Venugopal 1981). It also appears to be restricted to the margin of the Matapedia

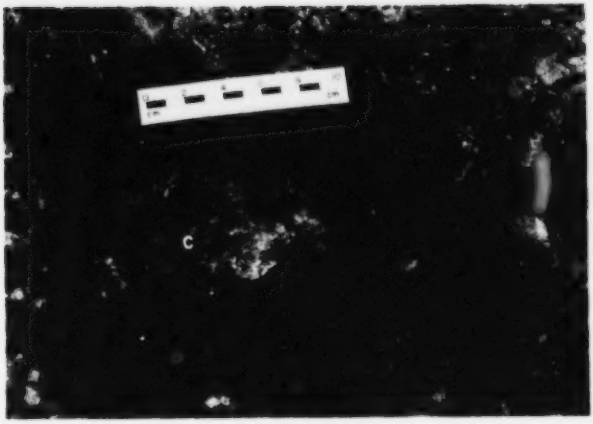


Figure 30. Polymictic conglomerate containing cobble of conglomerate (c) south of Northville.

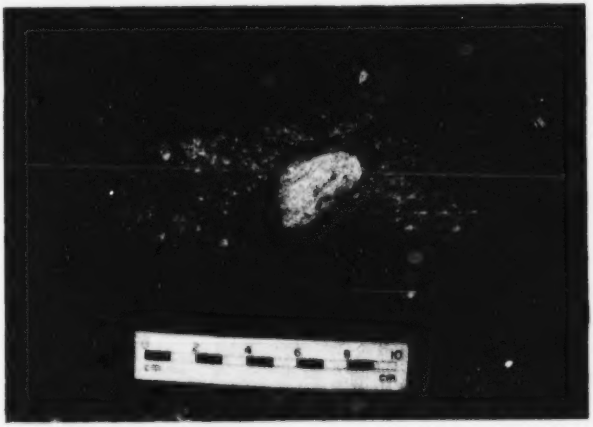


Figure 31. Flow-banded rhyolite pebble in conglomerate on Day Brook.

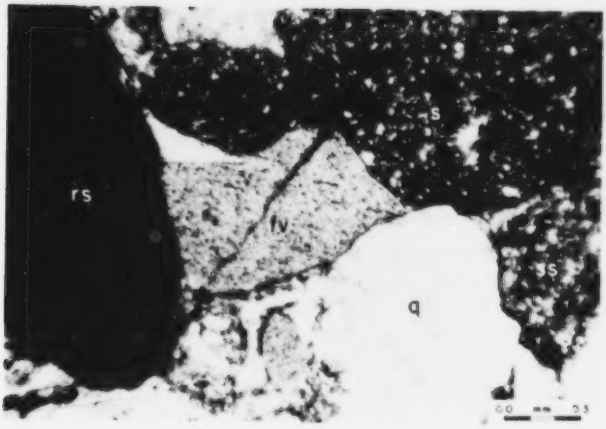


Figure 32. Polymictic conglomerate displaying clasts of red slate (rs), quartzite (q), felsic volcanic (fv), siltstone (s), and sericite schist (ss).

Basin as early Gedinne fossils occur some distance to the northwest (St. Peter 1979).

The erosional episode is believed to be related to uplift of the Miramichi Anticlinorium to the south and east (Figure 1). During the uplift, the bordering rocks of the overlying Smyrna Mills Formation were presumably eroded shedding detritus into the Matapedia Basin during Wapske Formation time.

Mafic volcanic rocks (Unit Dmvg) of the Wapske Formation occur as a number of isolated lenses. The volcanics are exposed in I-16 map-area near Big Teague Brook; in I-17 map-area along Lower Howard Brook, northwest of Golden Ridge, southeast of Lindsay Spring, and at Garvey Mountain; and in I-18 map-area west of Jericho.

The mafic volcanic rocks are massive and vesicular. The vesicles range from 1 to 20 mm in diameter and are filled with chlorite, calcite, and minor epidote. In outcrop, the rock is locally seen to contain 2 to 50 per cent phenocrysts of plagioclase. The volcanics adjacent to the faults at Big Teague Brook and Garvey Mountain are noteably brecciated and display abundant narrow veins of intergrown light green prehnite, chlorite, and epidote.

The mafic volcanic rock comprises 40 to 70 per cent felty plagioclase (andesine) with secondary intersertal chlorite, epidote, calcite, and submicroscopic material. The plagioclase is commonly in part replaced by sericite, epidote and locally prehnite. The volcanics at Garvey Mountain contain rare euhedral clinopyroxene crystals pseudomorphously replaced by chlorite.

Brachiopods collected at five localities (Table 5) give an upper Helderberg (early middle Lower Devonian, see Figure 33) age for the Wapske Formation (Boucot *written communication* 1980). The assemblages in siltstone beds at localities 96928 on Hamilton Brook and 96931 and 96932 on Lower Howard Brook in I-17 map-area are autochthonous whereas the shells, in sandstone beds, at localities 96938 on Hamilton Brook and 96949 on Day Brook are somewhat fragmented and suggest "some" transportation has taken place (Boucot *op.cit.*).

Brachiopods were collected by Anderson (1968) at locality 24042 and 25444 on a hill in I-17 map-area about 1 km north of Knowlesville. The shells were examined by L.M. Cumming (reported in Anderson, p. 28-29, 1968) and suggest a probable Lower Devonian age.

Flaggy sandstone beds in the Wapske Formation locally contain abundant highly carbonized plant fragments. The sandstone at locality 96942 in the stream bed of North Becaguimec River 1.77 km southwest of the mouth of Lower Howard Brook in I-18 map-area contains diverse, but poorly preserved spores (Table 6). The identifiable taxa (McGregor 1980*a*) indicate a latest Early Devonian or earliest Middle Devonian (late Ems or early Eifel) age (Figure 33).

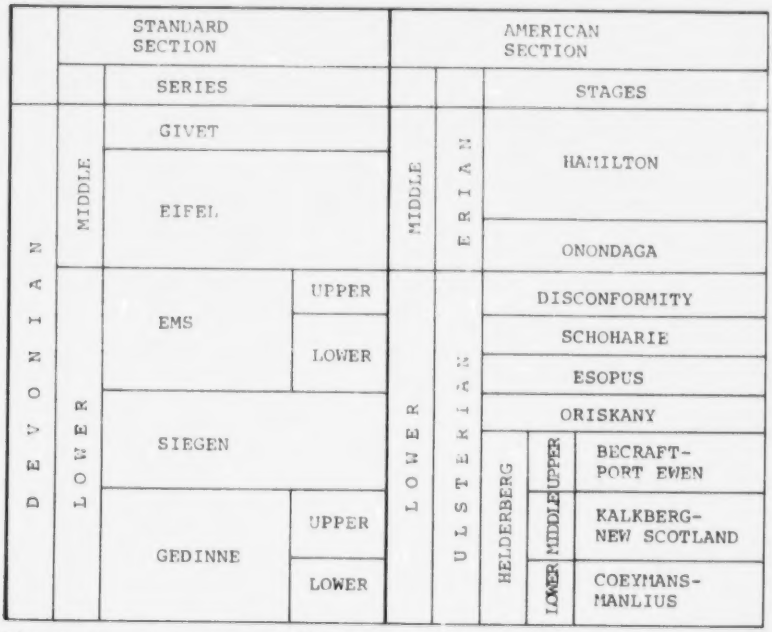


Figure 33. Lower and Middle Devonian time scale (after B.A. Hall 1970)

TABLE 5.

Brachiopods from Wapske Formation

Species* \ Locality	96928	96931	96932	96938	96949
Howellella cf. *cycloptera*	X		X	X	X
Coelospira cf. *camilla*	X			X	X
Leptaena "rhomboidalis"	X	X		X	X
Atrypa "reticularis"	X	X		X	X
Megakozlowskiella sp.		X			?
Cyrtina sp.		X			X
Coelospira cf. *concava*		X			
Meristella sp.	X				
Pleurodictyum sp.	X				
Leptaenisca sp.		X			
Loxonema sp.		X			
Dalejina sp.				X	
Nucleospira sp.					X
Nanothyris sp.					X
Craniops sp.					X
Atrypina sp.		?			
Rhytistrophia sp.					?
Metaplasia sp.					?
rhynchonellid		X			
orthotetacid	X	X		X	
stropheodontid		X			
dalmanellid					X

*Fossils identified by A.J. Boucot 1980

TABLE 6.

Palynomorphs from Wapske Formation

Spores* \ Locality	96942	5413	5016	6230	23997
Grandispora douglastownense McGregor	X	X	X	X	X
Grandispora sp.	X	X	X	X	X
G. cf. *G. macrotuberculata* (Arkhangelskaya) McGregor	X	X			
Emphanisporites annulatus McGregor		X	X	X	X
E. rotatus McGregor		X	X	X	X
Diboliporites echinaceus (Eisenack) Richardson		X	X	X	X
D. radiatus Tiwari & Schaarschmidt	X				
D.? eifeliensis (Lanninger) McGregor		X			
Dictyotriletes emsiensis (Allen) McGregor		?	X		
Clivosispora verrucata McGregor		X	?		
Camarozonotriletes sextantii McGregor & Camfield					X
Camptozonotriletes sp.		X		X	
C. naperatus McGregor	?				
Clivosispora verrucata(?) McGregor			X		
Calamospora pannucea Richardson		X	X		
Apiculiretusispora brandtii Streel		?	X		
A. densiconata Tiwari & Schaarschmidt		X			?
A. arenorugosa McGregor			?		
Apiculatisporis microconus Richardson	X	X		X	X
Acinosporites ambiguus Tiwari & Schaarschmidt		?	X		
A. lindlarensis(?) Riegel	X				
Ancyrospora eurypterota(?) Riegel				X	X
A. sp.(?)		X			
A. netterscheimensis Riegel				X	

*Identifications by D.C. McGregor

Caley (p. 14, 1936) collected plant remains from a greenish argillite interbedded with conglomerate on the west bank of North Becaguimec River 650 m southeast of the bridge at Northville at locality 23997 in I-18 map-area. The spores retrieved from Caley's samples are, according to McGregor (1979), clearly late Ems or early Eifel in age.

Another collection was made by Caley from a locality which he describes as occurring on the "north branch of Becaguimec River immediately above Shaw's Mill". Shaw's Mill no longer exists, but was situated on the west bank of North Becaguimec River at the sharp turn where the Craig Brook Limestone is in fault contact with the Carlisle Formation. The nearest outcrop of Wapske Formation on North Becaguimec River lies 790 m to the north of Shaw's Mill and about 200 m south of fossil locality 5413. Caley's locality (GSC number 6230, Table 6) is not shown on I-18 map-area because it can not be precisely located. The spores there are of latest Ems or earliest Eifel age (McGregor 1980*b*).

An excellent spore assemblage has been retrieved from beds on the south side of North Becaguimec River 1.42 km north of the mouth of Craig Brook at locality 5413. The samples were collected by D.C. McGregor in 1959, and are probably from the same outcrop that Anderson (p. 28, 1968) describes as locality 4273. The spores give an age close to the Early/Middle Devonian boundary (McGregor 1980*b*).

Plant remains were collected by L.M. Cumming in 1957 from strata near, or possibly at, locality 5413. The locality (GSC number 5016, Table 6) is not shown on I-18 map-area since it can not be accurately located. Age and comments are the same as for locality 5413 (McGregor 1980*b*).

The brachiopods are late Helderberg (early Siegen). The spore-bearing beds of late Ems or early Eifel age are the youngest rocks of the Wapske Formation. The paleontological age assignments are in agreement with structural measurements from the southwestern part of I-18 map-area where, south of Northville, the spore-bearing beds at locality 23997 are in the core of a syncline that strikes northward under the Mississippian Carlisle Formation. The beds crop out again along North Becaguimec River, north of Carlisle, where they are presumably part of the same syncline faulted against Middle Ordovician and Silurian rocks to the west.

The Wapske Formation records a change from marine brachiopod-bearing rocks in the lower part of the section to terrestrial plant-bearing rocks in the upper part. Boucot (*written communication*, 1980) interprets the brachiopods to be subtidal photic zone assemblages. McGregor (1979, 1980*b*) found no marine palynomorphs such as acritarchs, scolecodonts, or chitinozoans at localities 5413, 5016, 6230, and 23997. He infers that the spore-bearing beds were deposited in a terrestrial environment. His observations are supported by the presence of well preserved *Euestheria raymondi* at locality 23997 (Caley 1936; Anderson 1968). Euestheria are restricted to fresh or brackish water habitats (Easton, p. 545, 1959).

DEVONIAN

The rocks herein assigned to the Devonian System are exclusively intrusive and largely confined to the eastern part of the area. The rocks are divided into three units of mafic composition - Becaguimec Lake Gabbro (Unit Dm_1), monzodiorite (Unit Dm_2), and diabasic gabbro (Unit Dm_3) - and four units of felsic composition - granodiorite (Unit Df_1), monzogranite and felsite (Unit Df_2), and Juniper Barren Granite (Unit Df_3). The plutonic rocks are classified after Streckeisen (1973).

Becaguimec Lake Gabbro (Unit Dm_1): The Becaguimec Lake Gabbro is the largest mafic pluton in New Brunswick with an area of about 200 km^2. It is elongate in a north-south direction extending from Juniper in I-16 map-area to Lawrence Peak 10 km southeast of I-18 map-area (Anderson 1968; Venugopal 1979). The pluton consists of gabbro with minor associated gabbro pegmatite and granodiorite veins. The pluton contains abundant hornfelsic xenoliths and roof pendants of Lower Devonian siltstone, sandstone, and rhyolite in I-16 and northern I-17 map-areas.

The gabbro is mottled dark green or dark grey and white, medium- to coarse-grained, and typically subophitic. Microscopically the gabbro is seen to comprise abundant plagioclase (andesine to labradorite), lesser clinopyroxene, minor disseminated opaques, and accessory apatite and sphene. In places, the rock contains intersertal quartz and orthoclase. Plagioclase tends to be dusted with sericite. Clinopyroxene is typically mantled or entirely replaced by hornblende. Both pyroxene and hornblende are commonly pseudomorphed by chlorite and actinolite.

Many outcrops of gabbro show evidence of mild to strong deformation. Fractures in mildly deformed rock are filled by chlorite, actinolite, minor biotite, prehnite, and locally pumpellyite. Highly deformed rocks possess a mylonitic fabric defined by granulated and rotated plagioclase porphyroclasts and subparallel hornblende and biotite. The hornblende and biotite are metamorphic and generally post-mylonitic since they display no evidence of strain. An outcrop of mylonitic gabbro adjacent to the Catamaran Fault, south of the CNR tracks in northern I-16 map-area, shows two generations of actinolite. The earlier crystals are fibrous, crenulated, and rotated into the mylonitic layering. The later crystals are blade-like and undeformed (Figure 34).

The gabbro in I-16 and northern I-17 map-areas is locally transected by veins and dykes of biotite granodiorite (Figure 35). The veins (symbol "gd" on Plates 80-35A and 80-36A) commonly contain resorbed xenoliths of gabbro. In exposures where granodiorite is extensive, the gabbro is seen to be hybridized, forming zones of diorite. In thin section, the hybrid diorite displays altered plagioclase from the gabbro and fresh plagioclase from the granodiorite. The diorite contains up to 15 per cent quartz and 3 per cent microcline in more felsic-rich patches.

Gabbro pegmatite exposed in I-18 map-area (see "pg" symbol on Plate 80-37A) consists of plagioclase and amphibole crystals ranging from 1 to 3 cm in length. In an outcrop 300 m north of Owl Lake, pegmatite forms irregular pods that grade into the medium-grained gabbro host. The pegmatite on a hill 1 km

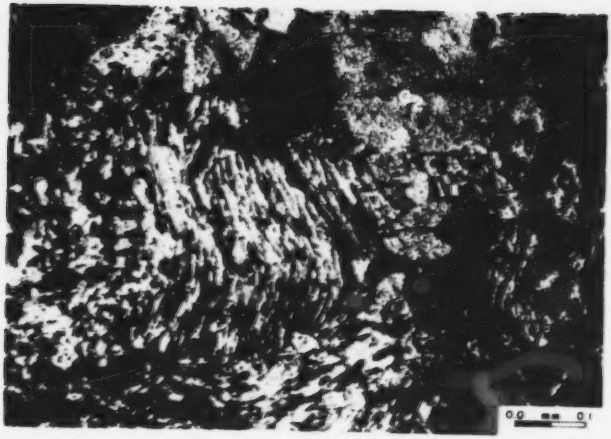


Figure 34. Crenulated and deformed actinolite (a_1) overgrown by blades of actinolite (a_2).

Figure 35. Gabbro in lower part of photo cut by composite dyke of diabasic trap (dark grey) and granodiorite (light grey).

south of Lake Brook forms a relatively large body encompassing several adjacent outcrops. The pegmatite is mylonitized on the south slope of the hill and contains rounded plagioclase and actinolite porphyroclasts apparently pseudomorphous after primary hornblende on pyroxene. The actinolite is overgrown by blades of hornblende that are off-set by late fractures. The fractures are in turn, filled with later actinolite. Plagioclase porphyroclasts contain radiating crystals of prehnite.

The Becaguimec Lake Gabbro lies astride the boundary between the Chaleur Bay Synclinorium and Miramichi Anticlinorium (Figures 1 and 2). In this regard, the tectonic setting of the pluton is similar to the Clearwater Brook Gabbro which lies 40 km to the northeast (Crouse 1978). Both gabbro bodies are elongate, north-trending, and locally intensly sheared. The Becaguimec pluton apparently intruded a pre-existing suture zone between the Chaleur Bay Synclinorium and Miramichi Anticlinorium. The suture zone, as marked by the Catamaran Fault, was active during and after intrusion as evidenced from the locally intense mylonitic fabric in the gabbro.

Monzodiorite (Unit Dm_2): Several small bodies of monzodiorite are exposed between MacIntosh and Lake Brooks in I-18 map-area and another occurs within the Costigan Mountain Formation and Becaguimec Lake Gabbro in northern I-17 map-area.

The monzodiorite is medium-grained, massive, and equigranular. It is spatially associated with, but readily distinguished from the Becaguimec Lake Gabbro. The rock is characterized by pink and dark grey mottling on both fresh and weathered surfaces.

Thin section examination of five samples of the rock show a range in mineral content: plagioclase (andesine, 50 to 60 per cent), orthoclase (1 to 20 per cent), clinopyroxene (10 to 25 per cent), quartz (2 to 10 per cent), and accessory opaques, sphene, and apatite. The quartz and orthoclase are typically intersertal and micrographically intergrown. In addition to the primary minerals listed above, the rock locally contains hornblende mantling clinopyroxene. The pyroxene is extensively replaced by actinolite and chlorite. Plagioclase is commonly dusted by sericite, minor calcite and epidote.

Diabasic Gabbro (Unit Dm_3): A relatively large stock of diabasic gabbro is exposed southwest of Juniper in I-16 map-area. Elsewhere in I-16 map-area, small gabbro bodies occur east of South Ridge and north of Shikatehawk River. In I-17 and I-18 map-areas several small stocks and dykes of gabbro occur within the Costigan Mountain Formation. A sill or dyke is exposed along the Wapske Formation-Smyrna Mills Formation contact at Lower Howard Brook.

The rocks of Unit Dm_3 comprise fine-grained, mottled light and dark grey diabasic gabbro and minor quartz-diorite. The diabasic gabbro consists of abundant plagioclase (andesine-labradorite), subordinate clinopyroxene, accessory opaques, sphene, apatite, and quartz. The plagioclase is commonly overgrown by fine-grained sericite, epidote, and rarely incipient prehnite and pumpellyite. Clinopyroxene is partially replaced by actinolite, chlorite, and epidote.

The gabbro bodies within the Tobique Group are locally vesicular. The vesicles are filled with chlorite, epidote, actinolite, and hematite. The north end of the stock, southwest of Juniper, is highly fractured and contains veins of quartz and feldspar.

In the southern part of the stock, southwest of Juniper, an outcrop of medium-grained quartz-diorite (see "qd" symbol on Plate 80-35A) contains abundant diabasic gabbro xenoliths ranging from 1 mm to 7 cm in length. The quartz-diorite consists of 65 per cent plagioclase (andesine, An_{45}), 15 per cent quartz, 5 per cent clinopyroxene, 5 per cent hornblende, 6 per cent chlorite, 2 per cent disseminated opaque minerals, and accessory apatite and sphene. The hornblende is at least, in part formed from the clinopyroxene; chlorite is intersertal. The quartz contains minor micrographically intergrown potash feldspar.

Xenoliths of hornfelsic siltstone, sandstone, and rhyolite of the Tobique Group are common in the diabase bodies. Wapske Formation rocks are metamorphosed to biotite grade hornfels adjacent to the stock southwest of Juniper. The north-trending dyke at Lower Howard Brook in I-17 map-area is seen to intrude the Smyrna Mills Formation; green siltstone along the dyke contact is noticeably indurated.

In southeastern I-16 map-area a very fine-grained diabasic trap dyke intrudes the Becaguimec Lake Gabbro. The trap dyke is intruded by biotite granodiorite of map-unit Df_1 (Figure 35). Diabase dykes intrude monzodiorite of Unit Dm_2 and quartz monzonite of Unit Df_2 along North Becaguimec River about 1 km northwest of Lake Brook. The dykes are irregular in outline suggesting they intruded a host that was too hot to fracture brittlely. Diabase dykes intruding sedimentary rocks of the Costigan Mountain Formation (Unit Ds_1) along North Becaguimec River between Lake Brook and Black Brook contain recrystallized plagioclase grains and primary ferromagnesian mineral replaced by metamorphic ferroactinolite (Figure 36). The metamorphic assemblage in the dykes apparently resulted from the nearby contemporaneous emplacement of quartz monzonite.

Granodiorite (Unit Df_1): Five small bodies of biotite granodiorite are exposed in southeastern I-16 and northeastern I-17 map-areas. A sixth body occurs within the Becaguimec Lake Gabbro in northern I-16 map-area. Granodiorite, like that forming the six bodies, occurs as reticulate veins within the Becaguimec Lake Gabgro (Figure 35) and sedimentary rocks of Unit Ds_1 (see "gd" symbol on Plates 80-35A and 80-36A).

The biotite granodiorite is light grey, medium-grained, and equigranular. In most outcrops, the rock is replete with angular xenoliths of hornflesic sandstone, siltstone, minor gabbro and diabasic trap (Figure 37). The xenoliths range from less than 1 cm to greater than 1 m in length and commonly constitute 15 per cent of the rock. Exposures adjacent to the fault in northern I-16 map-area display a penetrative cataclastic foliation defined by rounded feldspar porphyroclasts and mylonitic quartz alternating with subparallel deformed biotite.

In thin section the granodiorite is seen to comprise about 20 per cent quartz, 50 per cent plagioclase (An_{25-40}), 10

Figure 36. Recrystallized diabasic trap dyke showing feathery plagioclase laths (light grey), metamorphic ferroactinolite (darker grey), and disseminated opaques (black).

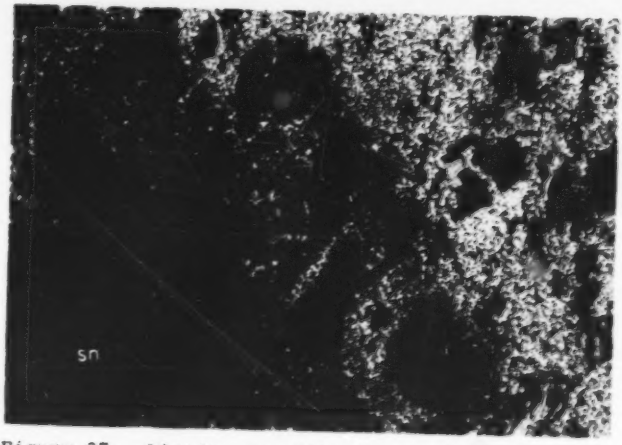


Figure 37. Biotite granodiorite containing xenoliths of siltstone (sn), sandstone (st), and gabbro (gb).

per cent orthoclase, 15 per cent biotite, accessory opaque mineral, sphene, apatite, zircon, and rarely allanite. Some plagioclase crystals are concentrically zoned from andesine cores to oligoclase rims.

The hornfelsic sandstone xenoliths contain metamorphic biotite, actinolite, and clinozoisite; the siltstone xenoliths contain abundant red biotite, poikiloblastic orthoclase, minor chlorite, muscovite, and tourmaline. Winkler (1967) ascribes such contact metamorphic assemblages to the albite-epidote-hornfels facies.

The biotite granodiorite clearly intrudes and postdates the Costigan Mountain Formation, the Becaguimec Lake Gabbro, and diabasic trap dykes. The lack of chilling in the granodiorite suggests it was intruded while the gabbro was still warm.

Monzogranite (Unit Df_2): The felsic intrusive rocks of Unit Df_2 occur mainly as a series of subcircular to elongate north-trending stocks in the eastern part of the area (Figure 2). Felsic dykes are associated with the stocks in I-18 map-area.

The unit comprises monzogranite and quartz monzonite, biotite-quartz-feldspar porphyry, minor microgranite and quartz monzodiorite. In outcrop, the monzogranite can not generally be distinguished from the quartz monzonite. In thin section, a significant quantity of the quartz in both rock-types is seen to be micrographically intergrown with alkali feldspar so that in the field an accurate estimation of the quartz content is not possible. Consequently, the two petrographically separable rock-types are grouped together, and termed simply "monzogranite".

A stock of medium-grained, biotite monzogranite underlies the area around Long Lake and Mud Lake in eastern I-18 map-area. The surface distribution of the monzogranite is partly interpreted from the stocks' magnetic expression. The body gives a negative magnetic anomaly of about 3,500 gammas against the surrounding Becaguimec Lake Gabbro which ranges from 3,700 to 4,600 gammas (Geological Survey of Canada, Coldstream Map 143G).

The medium-grained monzogranite is light pink and white, medium-grained, and equigranular to subporphyritic. The rock contains 1 to 2 per cent plagioclase phenocrysts ranging from 4 to 8 mm in length. A thin section of the rock shows the mineral content to be approximately: quartz (25 per cent), plagioclase (oligoclase, 45 per cent), orthoclase-orthoclase perthite (20 per cent), biotite (8 per cent), and accessory opaque minerals and apatite. The biotite is largely replaced by chlorite.

An outcrop of the monzogranite 300 m south of Silver Lakes contains xenoliths of the Becaguimec Lake Gabbro. Veins of the granite cut the gabbro as far south as Owl Lake. An outcrop of gabbro 200 m northwest of Owl Lake is intruded by an east-trending diabasic trap dyke of map unit Dm_3. Both the gabbro and trap are transected by leucocratic granite veins that are believed to be related to the monzogranite.

Monzogranite exposed along North Becaguimec River south of Lake Brook in I-18 map-area is pink, fine-grained, and equigranular to locally subporphyritic. The large north-trending

stock at the headwaters of Little Clearwater Brook in I-17 map-area displays subporphyritic texture. The rock there contains up to 25 per cent white-weathering feldspar crystals 2 to 3 mm in length set in a fine-grained matrix. The monzogranite exposures on Bradley Mountain in southeastern I-16 map-area are highly cataclastized, particularly along the fault south of Simpson Brook. Quartz and feldspar crystals are granulated, feldspar grains are epidotized, and the rock contains veins of quartz, feldspar, and epidote.

In thin section, the fine-grained monzogranite is seen to comprise 10 to 25 per cent quartz, 30 to 50 per cent plagioclase (oligoclase), 5 to 10 per cent potash feldspar, 10 to 35 per cent micrographically intergrown quartz and potash feldspar (Figure 38), and accessory sphene, apatite, and opaque minerals. The rock locally contains minor primary hornblende. The plagioclase is typically altered to fine-grained sericite; some crystals are overgrown by small irregular patches of epidote. Hornblende is largely replaced by chlorite.

Figure 38. Monzogranite showing sericite alteration of plagioclase and micrographic quartz and potash feldspar.

Biotite-quartz-feldspar porphyry occurs as a north-trending apophysis of the stock on the eastern side of Pokiok Brook in I-18 map-area. Its resistance to erosion produces a water falls where it crosses the eastern tributary of Pokiok Brook (Figure 39).

The porphyry varies from pink to locally light grey and is distinguished from the monzogranite by its porphyritic texture. Phenocrysts of quartz constitute 1 to 10 per cent of the rock and range from 1 to 7 mm in diameter. Feldspar phenocrysts comprise 2 to 20 per cent and range from 2 to 8 mm in length. The feldspar phenocrysts are mostly plagioclase; orthoclase phenocrysts are rare and commonly form mantles around plagioclase (Figure 40).

Figure 39. Resistant quartz-feldspar porphyry dyke on eastern tributary of Pokiok Brook.

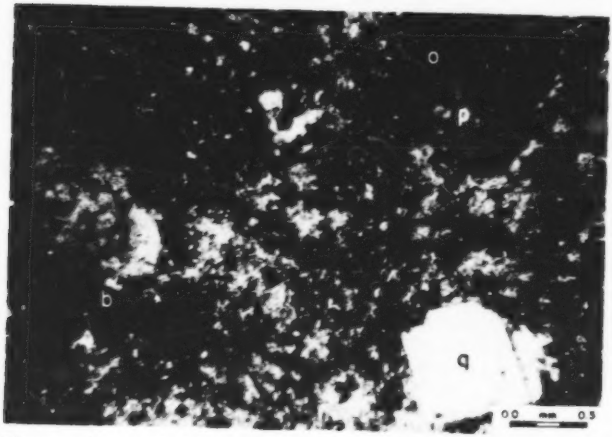


Figure 40. Biotite-quartz-feldspar showing phenocrysts of biotite (b), euhedral quartz (q), sericitic plagioclase (p) with mantle of orthoclase (o).

Biotite phenocrysts are less abundant and everywhere smaller than quartz and feldspar. They are typically replaced by chlorite, lesser sphene and opaque mineral. The groundmass of the porphyry consists of microcrystalline to granophyric quartz and feldspar, accessory apatite and opaque minerals, and patches of secondary chlorite and epidote.

Pink microgranite forms the western projection of the stock near the mouth of Pokiok Brook in I-18 map-area; several dykes of microgranite occur farther south on North Becaguimec River (Figure 41).

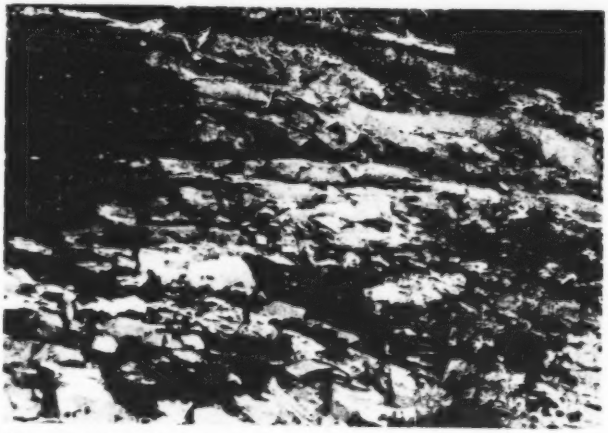


Figure 41. Massive microgranite on North Becaguimec River.

The rock is aphanitic and comprises microgranular quartz and feldspar. The feldspar is extensively dusted with opaque mineral, and partially replaced by calcite and sericite. The rock contains less than 1 per cent microphenocrysts of plagioclase.

Monzodiorite occurs along the south margin of the stock 850 m north of the summit of Bradley Mountain in I-16 map-area. The rock is similar to the monzodiorite of Unit Dm_2, but is too limited in extent to separate at the map scale. The monzodiorite contains highly digested xenoliths of the adjacent rhyolite of Unit Dfv.

The felsic rocks intrude the Costigan Mountain Formation and Becaguimec Lake Gabbro. Veins and dykes of monzogranite are particularly abundant within the western part of the Becaguimec Lake Gabbro along Lake Brook and MacIntosh Brook in I-18 map-area.

On North Becaguimec River, about 1 km northwest of the mouth of Lake Brook, quartz monzonite shows a gradational contact with the monzodiorite of Unit Dm_2. Neither rock is chilled, one against the other, and it seems certain their emplacement is little separated in time.

Within the same quartz monzonite outcrop, there are xenoliths of siltstone. The xenoliths are very irregular and have flame-like protrusions that are molded into the quartz monzonite host. It is concluded from this, that, at this locality the siltstone was probably soft and water-saturated when the quartz monzonite was emplaced. Also in the same outcrop, a narrow layer of interbedded quartzose sandstone and siltstone is intruded by a diabasic trap dyke of Unit Dm_3. Where the dyke cuts the sediments, it has a hyaloclastic margin, again suggesting the sediments contained water. The intrusive contact relationships seen here strongly imply (a) both the mafic dyke and quartz monzonite were emplaced prior to the complete lithification of the Costigan Mountain sedimentary rocks, and (b) the intrusion of the dyke and quartz monzonite was nearly synchronous (see above under Diabasic Gabbro, Unit Dm_3).

The intrusive relationships just described, infer the felsic intrusive rocks immediately postdate the Lower Devonian (Helderberg) Costigan Mountain Formation. Rb-Sr whole-rock isochron dates on the Costigan Mountain Formation and the adjacent sub-volcanic Redstone Mountain Granite in the Gulquac River area about 60 km to the northeast corroborate this conclusion. The Costigan Mountain Formation gives an isochron of 409±35 Ma; the Redstone Mountain Granite dates at 409±25 Ma (Fyffe and Cormier 1979).

Juniper Barren Granite (Unit Df_3): The Juniper Barren Granite underlies the eastern part of I-16 map-area. The granite pluton was named by St. Peter (1981) to describe a body of mainly biotite granite lying immediately to the east and north of I-16 map-area. The pluton is continuously exposed for over 25 km from Little Clearwater Brook in the south in J-16 map-area to Fifteen Mile Brook in the north in J-15 map-area.

A description of the granite and its structural-intrusive relationships with adjacent rocks of the Miramichi Anticlinorium has been given by St. Peter (*op. cit.*). Only the main biotite granite is exposed in I-16 map-area.

The biotite granite is mottled pink, light and dark grey, medium-grained, and equigranular to subporphyritic (Figure 42). The rock is massive, except along the Catamaran Fault where it contains narrow cataclastic zones. A thin section of the granite gives the following mineral content: 25 per cent quartz, 40 per cent microcline and microcline perthite, 25 per cent plagioclase, 8 per cent biotite, and accessory apatite, zircon, and allanite. A few microcline crystals form subphenocrysts up to 7 mm in length. Some plagioclase grains are concentrically zoned; most are partially replaced by fine-grained white mica. Biotite shows limited replacement by chlorite.

Just south of the pluton, about 70 m east of I-16 map-area, a dyke of Juniper Barren biotite granite intrudes the Ordovician mylonitic granite of Unit Of. The dyke represents the only clear evidence in this area that the granite intrudes - rather than being in fault contact with - the Cambrian-Ordovician rocks of the Miramichi Anticlinorium. The Juniper Barren Granite is in fault contact with the Becaguimec Lake Gabbro and Tobique Group along the Catamaran Fault.

Figure 42. Juniper Barren Granite - massive, medium-grained, equigranular biotite granite.

The Juniper Barren Granite has not been isotopically dated. The massive character of the rock suggests it is a late Acadian pluton of Devonian age (St. Peter 1981; Fyffe *et al.* 1981).

MISSISSIPPIAN

Carboniferous redbeds were recognized in this part of New Brunswick many years ago (Bailey 1886; Caley 1936). Anderson (1968) separated the redbeds from an overlying sequence of grey sandstone and conglomerate. The grey rocks have been assigned a Pennsylvanian age in the present report.

The rocks in this report included in the Mississippian System comprise a basal unnamed formation of mafic volcanic rock and an overlying sequence of redbeds named the Carlisle Formation.

Mafic Volcanic Rock (Unit Mmv): Mafic volcanic rocks are exposed at the mouth of Lake Brook, and south of Owl Lake in southeastern I-18 map-area. The volcanics south of Owl Lake continue about 3.5 km to the southwest of I-18 map-area, where they have been mapped by Venugopal (1979).

The thickness of the mafic volcanic flow at Lake Brook can safely be estimated at less than 20 m. Although the lower and upper contacts have not been seen, the relatively close outcrop control, and the gentle topography necessitates the limited thickness.

The mafic volcanic rock is brown-weathering, dark grey, fine-grained, and vesicular. The vesicles are filled by chlorite, calcite, and lesser hematite. In outcrop, the rock displays subhorizontal layering, along which it parts into thick slabs. In thin section the layering is seen to be defined by subtrachytic

flow alignment of feldspar laths (Figure 43). The layering in the exposures along Lake Brook is transected by upright columnar joints.

Figure 43. Subtrachytic mafic volcanic rock with calcite amygdule (Unit Mmv).

The rock contains very abundant plagioclase, minor disseminated opaque minerals, and accessory sphene and quartz. The rock is characterized by the absence of primary ferromagnesian minerals.

The subhorizontal disposition of layering, and the geographic location along the margin of the Carlisle Formation, strongly suggest the volcanic rock is a local basal formation of the Carboniferous succession. Subordinate evidence is given by the exposures at Lake Brook where the volcanic rock is not cut by felsite veins and dykes that are so common in adjacent outcrops of the Devonian Becaguimec Lake Gabbro and Costigan Mountain Formation. The mafic volcanics are, therefore, assigned a Mississippian age.

Carlisle Formation (Unit Ms): The sequence of redbeds that unconformably overlies the Devonian rocks in the area is here assigned the name Carlisle Formation after the community of Carlisle, situated in central western I-18 map-area. The formation is mostly exposed in southwestern and north-central I-18 map-area. An elongate north-trending arm extends north of Tamarac Brook in I-17 map-area. The eastern limit of the redbeds more or less follows the southeastern course of North Becaguimec River. The formation is continuously exposed beyond Lower Cloverdale, 7 km south of I-18 map-area (Anderson 1968; Venugopal 1979).

The thickness of the Carlisle Formation in I-18 map-area, as taken from the cross-section "AA" on Plate 80-37A, is estimated at 150 to 200 m. The thickness estimate assumes the pre-Carlisle erosion surface was relatively flat and peneplained, and that no faults have repeated or otherwise complicated the section.

The Carlisle Formation comprises red polymictic conglomerate interbedded with red lithic sandstone, and minor red mudstone. Red breccia and grey arkose are locally present at the base of the formation.

Red conglomerate is by far the most abundant rock-type. It occurs throughout the formation in beds ranging from 0.5 to 3 m in thickness. The rock consists of oblate to spherical, well rounded granules, pebbles, cobbles, and typically a few boulders in a muddy to sandy matrix (Figure 44). The clasts lie parallel or slightly inclined to bedding. The clasts comprise a multitude of rock-types - both externally derived and intraformational. Most of the externally derived clasts can be confidently matched with lithotypes exposed to the east in the Chaleur Bay Synclinorium and Miramichi Anticlinorium. They include: abundant quartz, quartzite, rhyolite, quartz-feldspar porphyry, and micaceous quartzose sandstone; minor red chert, grey siltstone, and medium-grained granite; and rare gabbro, gneiss, foliated granite, green chert, and sericite schist. The intraformational clasts consist of red sandstone and mudstone that are diagnostic and aid in the distinction of the conglomerate from the underlying conglomerate of the Devonian Day Brook sequence.

Figure 44. Carlisle Formation, polymictic conglomerate showing poorly sorted but well rounded clasts. Scale is 10 cm in length.

The conglomerate beds are typically massive and rarely display any evidence of grading. Outcrops along North Becaguimec River and Brummagen Brook in I-18 map-area commonly show several successive conglomerate beds. The only way of distinguishing one bed from an other is by planes of separation along their base and top. The beds locally weather differentially giving outcrops a terraced appearance. Very rarely, a conglomerate bed exhibits cut-and-fill structure. Two exposures of pebble conglomerate on North Becaguimec River display tabular cross beds. One locality lies 0.9 km east of Upper Howard Brook and the other lies 1 km south of MacIntosh Brook. The paleocurrent direction at both localities is towards the northwest.

Red, friable, lithic sandstone occurs as interbeds within the conglomerate. The sandstone strata range from 10 cm to 1 m in thickness. Most beds show parallel lower and upper contacts. In places, the beds are lenticular, particularly where cut-and-fill in overlying conglomerate is developed.

The rock ranges from fine- to coarse-grained, and varies from matrix- to clast-supported (Figure 45). The sandstone in thin section is seen to contain - in addition to the clasts in common with the conglomerate - minor biotite, muscovite, and plagioclase, and accessory opaque minerals and tourmaline. The matrix of the rock consists of silt- and clay-size detritus with abundant hematite cement.

Figure 45. Carlisle Formation, medium-grained, clast-supported sandstone showing an assortment of lithic fragments and bent biotite (b).

Red mudstone is interbedded with the sandstone and conglomerate. The mudstone comprises perhaps 5 to 10 per cent of the formation and occurs in beds ranging from 30 cm to 2 m in thickness. The rock is poorly indurated and contains minor sand and silt detritus. Mudcracks have been observed at two localities: along North Becaguimec River 1.05 km east of Lower Howard Brook, and in an exposure on the north side of the road at the vertical turn 350 m west of Northville. The mudcracked rock east of Lower Howard Brook also contains very irregular, diffuse to coalescing, diagenetic limestone nodules. Similar nodules are present in beds exposed along North Becaguimec River: (a) 800 m southeast of Lower Howard Brook, and (b) 850 m south of Craig Brook.

Red sedimentary breccia occurs along the easternmost margin of the Carlisle Formation. The rock is best seen in several exposures along North Becaguimec River immediately north, and for about 1 km south of the mouth of MacIntosh Brook in I-18 map-area. Similar breccia outcrops are present along Little Pokiok Brook 3 km to the northwest.

The breccia comprises between 40 and 75 per cent angular pebbles, cobbles, and boulders of quartz-feldspar porphyry, rhyolite, quartzite, and minor gabbro set in a red mudstone matrix (Figure 46). The angular clasts are obviously derived from the adjacent Costigan Mountain Formation, Becaguimec Lake Gabbro, and felsites of Unit Df_2.

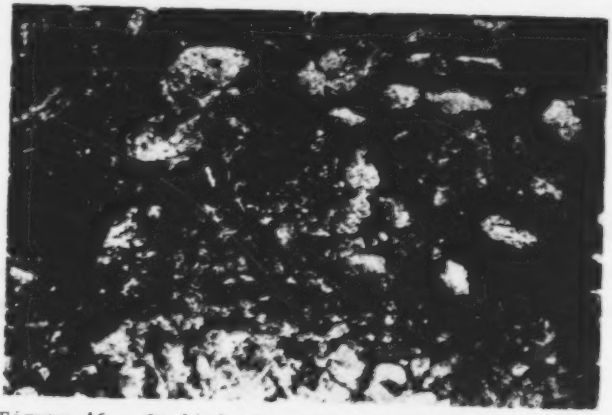


Figure 46. Carlisle Formation, sedimentary breccia containing angular clasts of felsite and rhyolite.

Light grey arkose occurs at the base of the Carlisle Formation 600 m southeast of the mouth of Little Pokiok Brook. There, on the south bank of North Becaguimec River, the basal contact of the formation is exposed. The contact is an angular unconformity: the underlying cataclastized Costigan Mountain rhyolite is overlain by the undeformed, gently dipping Carlisle Formation arkose. The arkose layer is exposed for 150 m along the south bank of the river, where it is overlain and interbedded along its upper (western) contact with red sandstone and conglomerate. The layer is about 10 m in thickness.

The arkose comprises poorly cemented coarse sand and granules of quartz (40 per cent), microcline (55 per cent), plagioclase (2 per cent), and detrital muscovite (2 per cent). Some of the microcline is replaced by sericite. The rock contains a few widely scattered, rounded pebbles of quartz.

The Carlisle Formation defines the basal unit of a post-Acadian basin. The formation, for the most part, lies with angular unconformity on Devonian rocks in the area. To the southwest of I-18 map-area, Anderson (Coldstream Map 1191A, 1968) shows the Carlisle Formation unconformably overlying Cambrian-Ordovician sedimentary rocks.

The clast content of the conglomerate and sandstone lithotypes suggest the major source area was to the east. Meager paleocurrent data corroborate an eastern provenance. The red sedimentary breccia, described above, at MacIntosh Brook and Little Pokiok Brook is believed to be a muddy talus deposit that formed along the face of a basin margin fault.

Rocks similar to those of the Carlisle Formation have been described by Bull (1972) as alluvial fan deposits. Accordingly, the strata represent conglomeratic and sandy debris flows, and minor mudflows. Nodular limestone caliche and mudcracks are common features in this type of terrestrial paleoenvironment (Bull *op. cit.*).

No fossils have yet been discovered in the Carlisle Formation. Anderson (p. 38, 1968) cited the occurrence of *Eucatheria raymondi* at fossil locality 23997, just south of Northville on the west bank of North Becaguimec River, as evidence that the redbeds are Carboniferous in age. The branchiopod locality is actually in the upper part of the underlying Devonian conglomerate. Estherids have been reported in the Devonian Trout Valley Formation 100 km to the west in north-central Maine (Neuman and Rankin 1980).

The Carlisle Formation is unconformably underlain by the late Early to early Middle Devonian conglomerate and conformably overlain by the Pennsylvanian Mountain View Formation. The time gap represented by the Acadian angular unconformity suggests the Carlisle Formation is considerably younger than the underlying conglomerate and for this reason, it is assigned a Mississippian age.

PENNSYLVANIAN

Mountain View Formation (Unit Ps): Mountain View Formation is the approved name assigned to the horizontally disposed grey sandstone and conglomerate overlying the Carlisle Formation. The Mountain View beds underlie a plateau in southern I-18 map-area (Figure 3) and northern I-19 map-area (see also Anderson 1968; Venugopal 1979). The preserved part of the section is about 100 m in thickness.

The Mountain View Formation comprises light grey quartzose sandstone interbedded with light grey quartz pebble conglomerate. Both rock-types are light brown and very friable on weathered surfaces. The sandstone varies from medium-grained to granular and occurs in beds ranging from 30 cm to 3 m in thickness. The conglomerate contains 5 to 30 per cent quartz and minor chert pebbles in a coarse-grained to gritty quartzose matrix.

A thin section of flaggy quartzose sandstone has the following clast content: quartz (70 per cent), felsite (15 per cent), slate (3 per cent), muscovite schist (2 per cent), quartzose wacke (2 per cent), feldspar (1 per cent), and accessory muscovite, biotite, zircon, sphene, and opaque mineral. The matrix of the rock consists of white mica, minor chlorite and limonite.

Outcrops along the upper slope of the escarpment northeast of Mountain View display the most revealing bed forms of the formation. There, thick beds of pebble conglomerate are typically overlain by medium to thick beds of low angle, tabular, cross-bedded sandstone. The tabular cross beds are overlain by trough cross-bedded or flaggy, parallel-bedded, medium-grained sandstone. Paleocurrent measurements on the cross beds show remarkable variation. Very limited data suggest a paleoslope towards the north and east. The sequential bed forms are believed to be the products of fluvial channel and point bar deposition (see the accounts

of Matthews 1974; and Walker and Cant 1980).

The Mountain View Formation conformably overlies the Carlisle Formation. The contact is exposed at the headwaters of an unnamed brook 1.3 km west of the mouth of MacIntosh Brook in I-18 map-area. The small brook cascades over grey Mountain View sandstone lying in sharp contact with very thick beds of red conglomerate and mudstone of the Carlisle Formation. Bedding in both formations at the contact is horizontal.

Fragments of *Calamites* sp. have been discovered in a coarse-grained flaggy sandstone, northeast of Mountain View at fossil locality 96951. The flora gives a general Pennsylvanian age for the Mountain View Formation (Copeland *written communication* 1979).

STRUCTURAL GEOLOGY

The map-area is underlain by three structurally distinct sequences of rock: (1) Cambrian and Ordovician rocks of the Miramichi Anticlinorium to the northeast; (2) Ordovician to Devonian stratified rocks of the Matapedia Basin (Aroostook-Matapedia Anticlinorium and Chaleur Bay Synclinorium) in the west; and (3) Mississippian and Pennsylvanian rocks within a small basin in the south (Figure 1).

The regional structural geology of the pre-Mississippian rocks is summarized by Rodgers 1970, Rast and Stringer 1975, and Ruitenberg *et al.* 1977.

Polydeformation within the Miramichi Anticlinorium is attributed to the Ordovician Taconian Orogeny and the late Lower to Middle Devonian Acadian Orogeny (Helmstaedt 1971; Poole 1976; Ruitenberg *et al.* 1977). The limited exposure and small portion of the report area underlain by rocks of the Miramichi Anticlinorium restricts structural interpretation of these rocks. Furthermore, the rocks of Units €Op, Om, and Of are mylonitic adjacent to the Catamaran Fault, and consequently their regional fabrics are largely obscured. An exception to this is seen in an outcrop of amphibolite of Unit Om in southeastern I-16 map-area. The amphibolite possesses a well preserved foliation (Figure 5) defined by aligned hornblende, porphyroclasts of plagioclase, and minor polygonal biotite. The foliation is cut by a later crenulation cleavage marked by small polygonal biotite and hornblende that are coplanar with the axial surface of the folds in Figure 5. Similar amphibolite to the east of the area shows comparable structure. The amphibolite foliation is coplanar with a regional gneissosity in associated paragneiss and granite. The gneissosity has been correlated with a regional greenschist grade Taconian fabric elsewhere in the Miramichi Anticlinorium (Irrinki 1978; St. Peter 1981).

The Ordovician to Devonian rocks of the Aroostook-Matapedia Anticlinorium and Chaleur Bay Synclinorium have undergone a regionally pervasive deformation giving rise to upright folds with an axial surface cleavage. The deformation has been attributed to the Acadian Orogeny (Donohoe and Pajari 1974; Ruitenberg

et al. 1977). To the southwest of the report area, near Woodstock (Figure 1), the regional Acadian structure in the Carys Mills Formation is predated by macroscopic folds displaying overturned limbs. It is suggested that these early folds are possibly a late manifestation of the Ordovician Taconian Orogeny (Rast *et al*. 1980). No pre-cleavage folds were observed in the present area.

The Acadian structures in the report area fall into three domains. The boundaries of the domains are coincident with the Knowlesville Fault and the Ashland-Highlands Fault (Figure 2). On the northwest side of the Ashland-Highlands Fault the rocks of the Carys Mills, Smyrna Mills, and Wapske Formations are folded into mesoscopic and macroscopic, upright, tight folds with pervasive axial surface cleavage. The stereographic plots (Figure 47a and b) of bedding (S_0) and cleavage (S_1) show the axial planes of the folds strike N40°E and dip 80°NW. The folds plunge 6° towards N42°E. The stereographic diagrams demonstrate the nearly perfect coincidence of the axial planes and the northeast-trending cleavage.

The Acadian structures between the Ashland-Highlands Fault and the Knowlesville Fault have undergone considerable reorientation. The reorientation is attributed to the two bounding faults of the domain and the internal Armond and Windsor Faults. Bedding and cleavage in the block show a general northerly strike. In the southern part, bedding and cleavage strike north-northwesterly; in the northern part, bedding and cleavage strike north-northeasterly. Insufficient data is available to present a reliable accounting of fold geometry (Figure 47c and d). The map pattern displayed by the Smyrna Mills and Wapske Formations suggests the rocks are closely folded into upright or steep folds that have a moderate northerly plunge. This is most evident by the syncline cored by Wapske rocks west of Hemphill Corner in I-17 map-area, where the north-trending fold is transected by the Ashland-Highlands Fault.

The Carys Mills and lower Smyrna Mills Formations are absent east of the Ashland-Highlands Fault (St. Peter 1982*b*) where Wenlock to Ludlow rocks of the latter formation were deposited on Middle Ordovician Craig Brook Limestone. North-trending, steeply plunging folds in the overlying Silurian rocks implying a period of Taconian deformation within the Craig Brook strata.

The Tobique Group rocks east of the Knowlesville Fault along the western margin of the Miramichi Anticlinorium form a generally west-dipping sequence (Figure 48a) with a poorly developed, steeply dipping, north-northeasterly trending cleavage (Figure 48b). A reversal of this westerly dip occurs in the southwestern part of I-18 map-area where Wapske conglomerate is folded into a broad open syncline.

The strata of the Carlisle and Mountain View Formations within the Carboniferous basin in the southern part of the area show a gentle westerly dip (Figure 48c). The subhorizontal disposition of these rocks contrasts with the steeply dipping Ordovician to Devonian rocks (Figures 47a, 47c, and 48a) and attests to the presence of an Acadian unconformity.

The north-northwest-trending Catamaran Fault separates rocks of the Miramichi Anticlinorium from those of the Chaleur Bay

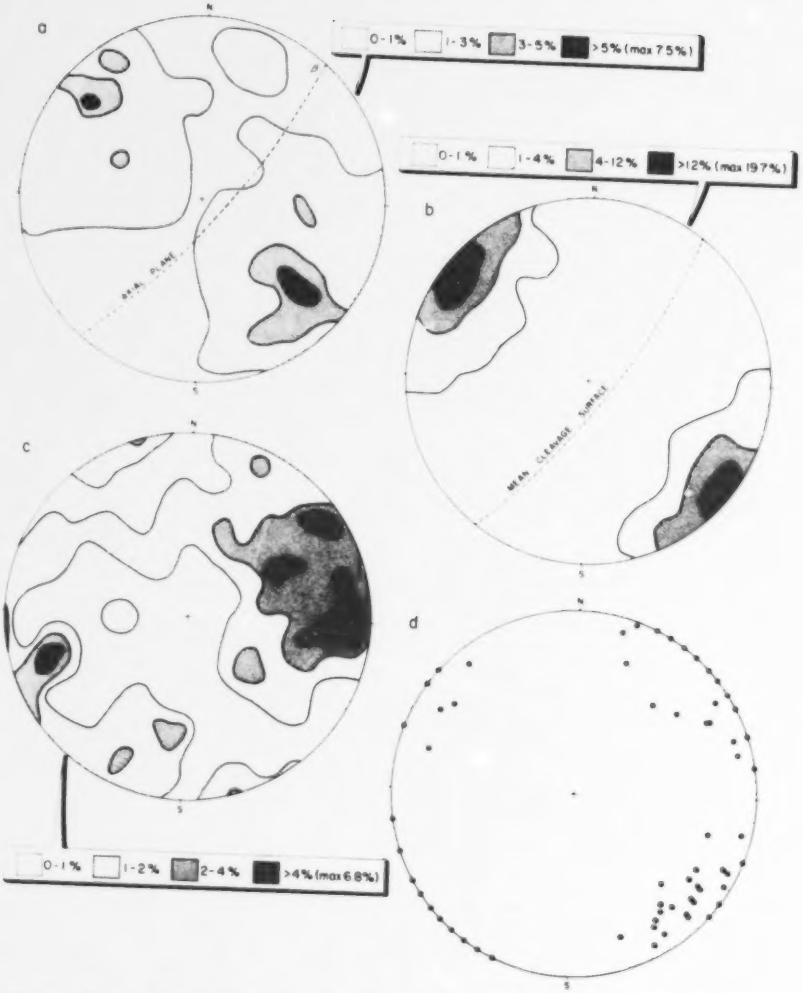


Figure 47a. Poles to bedding (S_0) west of Ashland-Highlands Fault, axial plane N40°E-80°NW, plunge (b) 6° towards N42°E

47b. Poles to cleavage (S_1) west of Ashland-Highlands Fault, mean cleavage surface N37°E-80°NW.

47c. Poles to bedding (S_0) between Ashland-Highlands and Knowlesville Faults.

47d. Poles to cleavage (S_1) between Ashland-Highlands and Knowlesville Faults.

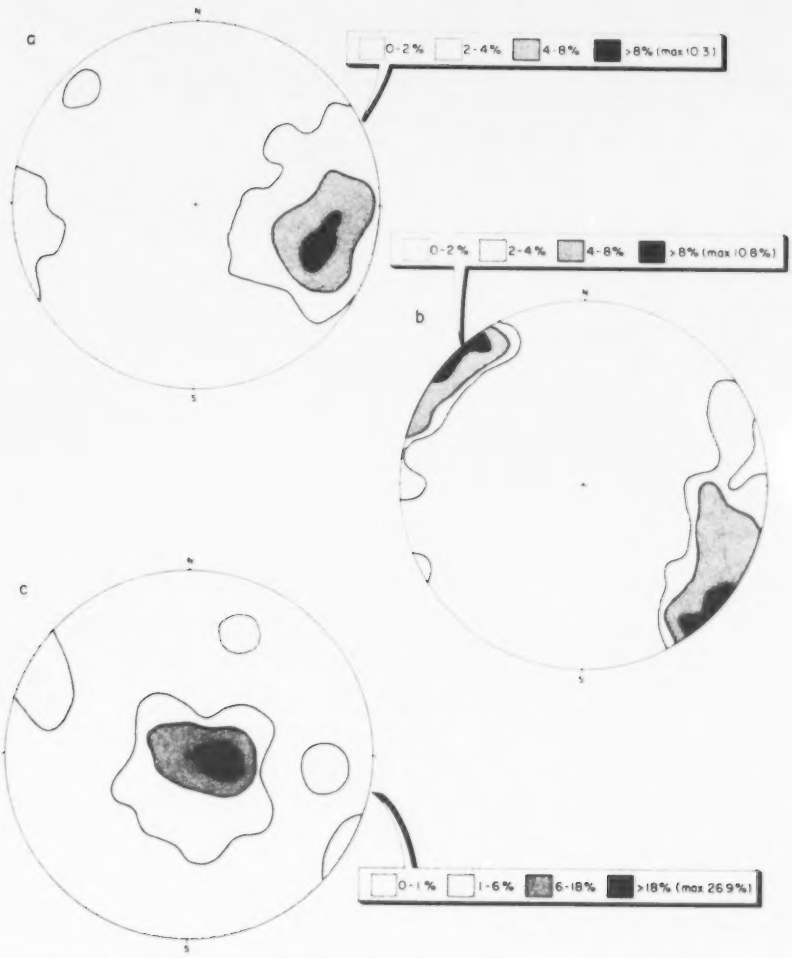


Figure 48a. Poles to bedding (S_0) east of Knowlesville Fault.
48b. Poles to cleavage (S_1) east of Knowlesville Fault.
48c. Poles to bedding (S_0) in Carlisle and Mountain View Formations

Synclinorium. A pervasive mylonitic fabric is developed in Lower Ordovician granite along the trace of this fault on Little Clearwater Brook (Figure 7). The fabric trends northwesterly and generally dips from 30° to 45° to the northeast. Drag folding of the fabric suggests rocks of the Miramichi Anticlinorium were thrust west-northwestward over those of the Chaleur Bay Synclinorium.

A few tens of metres to the east of the fault trace, the Juniper Barren Granite contains narrow northwest-trending cataclastic zones also dipping moderately to the northeast. Granodiorite veins intruding Devonian sedimentary rocks immediately to the west of the fault trace possess a steep foliation defined by the alignment of biotite and plagioclase.

It is evident that the Catamaran Fault controlled emplacement of the north-trending Becaguimec Lake Gabbro. Late movement along the fault produced local shear zones within the consolidated but still hot gabbro (Figure 34).

To the north of the report area, the Catamaran Fault swings to the east and displays right lateral displacement (Anderson 1972). This sense of movement is compatible with westward thrusting on the north-northwest-trending portion of the fault (St. Peter 1981).

Further evidence of westward thrusting is found at the mouth of Pokiok Brook in I-18 map-area. There, west-dipping felsic volcanic rocks to the east are in fault contact with sandstone and siltstone to the west. The fault trends northerly and dips 30° to the east (Figures 49 and 50). The relatively low angle of the fault plane suggests the volcanics were thrust over the sedimentary rocks.

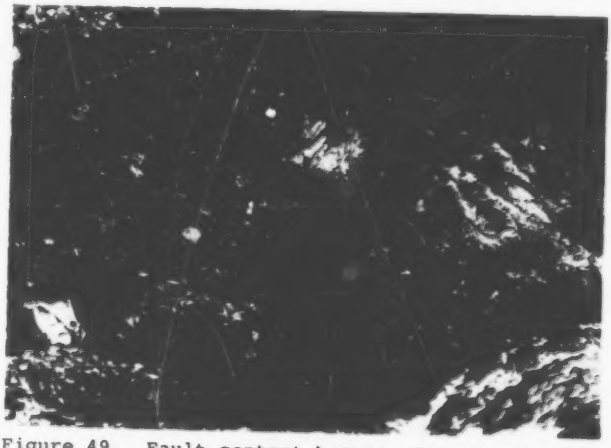


Figure 49. Fault contact between felsic volcanics (upper centre) and sedimentary rocks (left).

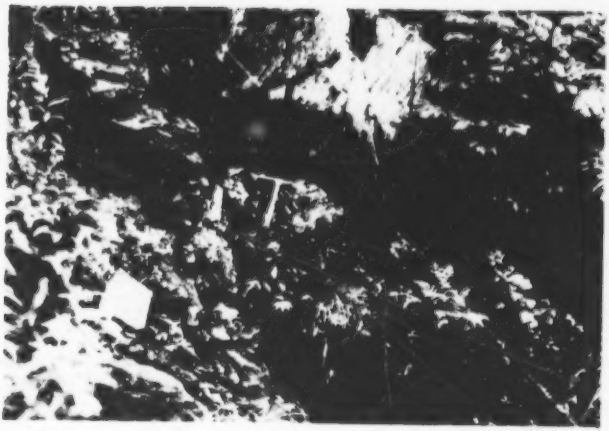


Figure 50. Close-up of fault contact between west-dipping volcanics (upper centre) and east-dipping sedimentary rocks (left).

A westward-directed thrust fault in southwestern I-16 map-area has been traced to Stickney 25 km to the southwest of East Glassville (St. Peter 1982*a*, *b*). In I-16 map-area the fault juxtaposes thickly bedded sandstone and slate of the Wapske Formation against phyllitic green slate of the Smyrna Mills Formation. The fault zone has been observed in a road-side exposure 8.5 km southwest of East Glassville. There, the rocks in the zone are marked by a shallow to moderate east-dipping cataclastic fabric with associated recumbent drag folds. About 2 km southwest of I-16 map-area the fault separates northwest-dipping and younging plant-bearing Wapske sandstone on the southeast from northwest-dipping Smyrna Mills siltstone and red slate on the northwest.

The northeast-trending Howard Brook Fault separates the Mississippian Carlisle Formation to the east from the Lower Devonian Wapske Formation to the west. The fault crosses North Becaguimec River at Howard Brook where gently west-dipping Carlisle redbeds are exposed 100 m east of steeper-dipping Wapske sandstone. A fault is necessary here since there is insufficient space to permit reversal of the dip in the redbeds required for them to lie unconformably on the Wapske strata (see section "AA" on Plate 80-37A). A similar situation was recognized to the southeast of the report area by Pavlides (p. 23, 1968). Near the headwaters of Upper Howard Brook and the mouth of Carl Brook in I-17 map-area the Howard Brook Fault has greatly steepened the Carlisle redbeds.

The north- to northeast-trending Knowlesville Fault extends from Foreston in I-16 map-area to North Becaguimec River in I-18 map-area. The fault separates a narrow belt of Smyrna Mills Formation to the west from Wapske Formation to the east. A sinstral cross fault offsets the main fault north of Hamilton Brook. In the north, the Knowlesville Fault was recognized on the basis

of younging directions; Devonian strata to the east of the fault consistantly face into Silurian rocks to the west. In addition, bedding trends tend to be oblique to each other across the trace of the assumed fault further supporting its existance. The constant steep westerly dip of the strata on both sides of the fault suggests the Silurian rocks were thrust eastward over the Devonian rocks along a relatively high angle thrust surface.

In the south, the presumed extension of the Knowlesville Fault can be seen at two localities on North Becaguimec River. About 1 km north of the mouth of Craig Brook, Devonian sandstone younging and dipping moderately westward is in fault contact with tightly folded Silurian limestone to the west. Less than 1 km farther upstream at fossil locality 96941 the sheared contact is again exposed.

Two generally north-trending faults have been recognized in northwestern I-18 map-area. The more easterly of these, the Armond Fault, is seen on North Becaguimec River where 600 m north of the mouth of Craig Brook, the Ordovician Craig Brook Limestone is in thrust contact, and overlies, the Devonian Wapske Formation (Figure 51). The same thrust surface is seen on a small brook to the west of the river at fossil locality 97516 where the fault marks the eastern contact of the Craig Brook Limestone against the Smyrna Mills Formation. Another 800 m to the north on a small brook, the Armond Fault juxtaposes Smyrna Mills calcareous sandstone on the west against Wapske conglomerate on the east. At this point the Craig Brook Limestone, which defines the sole of the thrust to the south, is no longer present. The fault continues northward separating Wapske strata younging and dipping to the west from Smyrna Mills strata lying to the west.

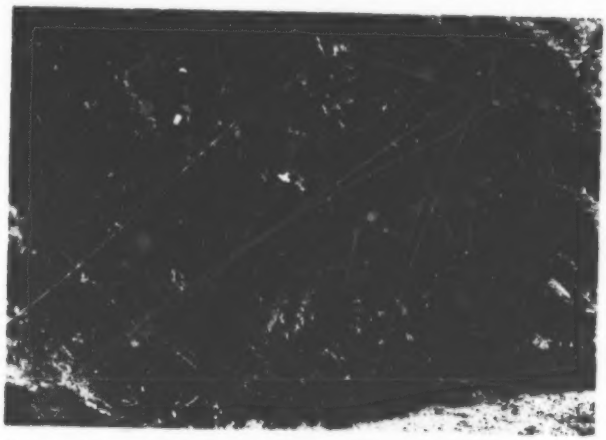


Figure 51. Contorted Lower Devonian Wapske Formation sandstone and siltstone overthrust by Ordovician Craig Brook Limestone (upper part of photograph).

The Armond Fault separates the Craig Brook Limestone from the Mississippian Carlisle Formation in the bed of North

Becaguimec River 300 m south of the mouth of Craig Brook. The contact is marked by a 2 m wide breccia zone containing sheared red polymictic conglomerate and graphitic chert (Figure 52). A short distance downstream, the Carlisle Formation is undeformed and subhorizontal (Figure 53).

Figure 52. Fault contact between Carlisle Formation (upper right) and Craig Brook Limestone (lower left).

Figure 53. Subhorizontal red conglomerate of the Carlisle Formation on North Becaguimec River.

The second north-trending fault in western I-18 map-area, the Windsor Fault, is exposed 700 m up Craig Brook from its mouth. Here, the eastern contact of the Craig Brook Limestone against Smyrna Mills slate is marked by a graphitic shear zone containing fragments of limestone. The shear zone strikes southeast and dips 45° westward. The western contact of the two formations is not exposed but the lack of shearing in closely adjacent outcrops makes an unconformity the preferred interpretation.

The Windsor Fault is interpreted to overstep the Armond Fault south of Craig Brook. The Craig Brook Limestone locally forms the sole of both these thrusts indicating they have sampled more deeply buried terrain than the Knowlesville Fault to the east.

In the northern part of the report-area the Knowlesville Fault and Armond Fault are cut-off by the northeast-trending Ashland-Highlands Fault which has been traced from south of Ashland to 10 km north of Juniper, a distance of 45 km. The latter fault also transects the Windsor Fault to the west of I-17 map-area (St. Peter 1982*b*). West of Hemphill Corner in I-17 map-area, the Ashland-Highlands Fault truncates a north-plunging syncline of Wapske strata. The contrast in structures across the fault has been described above.

Exposures along Coldstream in I-17 map-area near the Ashland-Highlands Fault are highly sheared and brecciated. Drag folds are commonly associated with numerous subsidiary faults within the sheared zone. Similar deformation has been observed in Wapska strata near Salmon Brook and Wiley Brook in central I-16 map-area.

To the southwest of the report area, the Ashland-Highlands Fault, the Windsor Fault and the Howard Brook Fault coalesce to become the Woodstock Fault (Figure 1) which thrusts rocks of the Carys Mills Formation eastward over Devonian and Carboniferous rocks (Venugopal 1981).

About 400 m southeast of Shikatehawk River in western I-16 map-area, a northeast-trending fault juxtaposes Silurian Smyrna Mills rocks against Devonian Wapske rocks. To the southwest, near Bristol on the Saint John River, the fault is seen to be a dextral transcurrent structure that off-sets the Carys Mills-Smyrna Mills contact greater than 5 km (Figure 1). The fault contact is exposed in the bed of a small brook just north of Bristol where the rocks are severely contorted, cut by numerous calcite veins, and intruded by northeast-trending, cataclastized diabase dykes (St. Peter 1982*a*).

ECONOMIC GEOLOGY

The earliest record of mineral exploration in the area dates back to the early nineteenth century when two limestone quarries - long since abandoned - were opened near Craig Brook (Bailey 1886).

The rather widespread presence of limestone led Stratmat

Limited in 1955 to map and drill five best known occurrences in the area. The results of their survey are recorded with the Department of Natural Resources, Mineral Resources Branch, Fredericton, New Brunswick, Assessment File Number 470462. Two of the limestone bodies drilled by Stratmat are outside the report area. One is near Windsor, 200 m west of I-18 map-area on the north side of the road leading west from Armond. The other is near Ashland about 5.3 km southwest of Carlisle (Anderson 1968). For a further description of these occurrences, the reader is referred to Hamilton (1965).

The remaining limestone bodies lie within I-18 map-area. The first, referred to as the Craig Farm limestone, consists of the Craig Brook Limestone exposed along the banks of North Becaguimec River opposite the mouth of Craig Brook. Stratmat sank thirteen diamond-drill holes into the limestone and outlined a relatively low-grade body 365 m in length and 80 m in width. The body was estimated to contain 4,164,000 tons with a grade of 50 per cent $CaCO_3$ and 50 per cent SiO_2.

The second limestone, commonly referred to as the Shaw Farm limestone, also occurs within the Craig Brook Limestone. It is exposed in the more northern of the two abandoned quarries south of Craig Brook (Hamilton 1965). From the quarry, the limestone bed strikes west of north and crosses Craig Brook from where it pinches out about 200 m to the northwest. Twelve drill holes put down by Stratmat suggest an estimated length of 520 m and a width of 27 m. About 2,000,000 tons of limestone with an average grade of 90.5 per cent $CaCO_3$ and 4.4 per cent SiO_2 is recoverable to a depth of 60 m. Of the four bodies studied by Stratmat, the Shaw Farm limestone is the highest grade the most amenable to excavation.

The more southerly quarry is underlain by limestone of the Smyrna Mills Formation. One drill hole intersected this body which was assumed to be continuous with the Craig Brook Limestone to the north.

Base metal occurrences in the area have been discovered and assessed by several mining companies during the past thirty years. In 1954, Stratmat Limited staked twenty-one claims around an abandoned shaft on the south side of Highway 107 in I-16 map-area. The shaft lies about 50 m west of Beaver Brook in silicified volcanic rocks of the Wapske Formation. The volcanics are cut by quartz veins containing disseminated chalcopyrite and pyrite (Assessment File Number 470294). Stratmat carried out an EM survey over the shaft area but failed to detect a conductor. The strike extension of the volcanic host is shown on Plates 80-35A and 80-36A. The rocks to the north (east of Big Teague Brook) are brecciated and contain veins of quartz, prehnite, chlorite, and epidote.

In 1955, the American Metal Company, Limited staked 30 claims over an airborne magnetic anomaly northwest of Foreston in I-16 map-area (Geological Survey of Canada, Juniper Magnetic Map 142G, 1953). Ground surveys detected two northeast-trending EM conductors that coincide with a positive gravity anomaly (Assessment File Number 470292). Five diamond-drill holes were sunk into the better EM conductor about 1.3 km northwest of Foreston. The bedrock comprises grey and green slate with minor interbedded sandstone and conglomerate. The rock contains numerous quartz

veins that are apparently related to the reverse fault along Lake Brook. The host rocks are reported to contain minor disseminations and stringers of chalcopyrite, sphalerite, and galena.

The sedimentary rocks of the Wapske Formation are highly indurated and hornfelsic near the American Metal Company claim group. This is particularly evident in exposures along the road 1.2 km north of Argyle. The hornfelsic bedrock infers an intrusive rock lies near the surface in this area; the associated positive gravity anomaly suggests the intrusive rock is mafic. An analagous situation is seen south of Beaver Brook, where biotite grade hornfels lies adjacent to the diabasic gabbro stock of Unit Dm_3.

In 1974 Atlantic Coast Copper and J.D. Irving Limited staked 18 claims immediately north of the largest east-trending tributary of Pokiok Brook in I-18 map-area. Soil and stream geochemistry, ground V.L.F. EM, and magnetometer surveys were carried out. A number of copper, lead, and zinc soil anomalies were located. A north-northwesterly trending magnetic anomaly and a closely adjacent EM conductor were defined in proximity to the more encouraging soil anomalies (Assessment File Number 470271). Follow-up work during 1976 located an induced polarization anomaly slightly off-set from the EM conductor. Two 90 m diamond-drill holes were bored using the geophysical targets. The first hole (approximately 67°16'08" longitude and 46°23'15" latitude) intersected barren mafic volcanic rocks of Unit Dmv_1. The second hole, located near the top of the hill east of Pokoik Brook (approximately 67°16'06" longitude and 46°23'02" latitude), encountered 27 m of barren rhyolite and rhyolite breccia, followed by 63 m of mafic volcanic rock containing disseminated magnetite, pyrite, and pyrrhotite. The iron-bearing minerals were apparently considered responsible for the magnetic and electromagnetic anomalies (Assessment File Number 470272).

Iron and manganese were discovered in slates of the Smyrna Mills Formation near Woodstock (Figure 1) during the early part of the nineteenth century (Anderson 1968). Exploration for iron and manganese mineralization began in the Glassville area with the discovery of manganiferous slate by Stratmat Limited in 1954. Three manganiferous shale lenses were outlined by a gravity survey in an area about 2 km northwest of East Glassville (approximately 67°24' longitude and 46°32' latitude). Two diamond-drill holes cored into one of the lenses revealed banded manganiferous hematite and secondary manganese mineralization (Assessment File Number 470295).

In 1955 National Management Limited discovered manganiferous and hematitic slate near Glassville, 6.5 km southwest of the Stratmat discovery. A gravity survey and five diamond-drill holes outlined a body of red ferruginous slate and manganiferous hematite. The body is about 240 m in length and 10 m in width; it comprises alternating thin bands of iron and manganese minerals with veins of quartz and associated rhodochrosite (Assessment File Number 470273). An estimated 500,000 tons of mineralized rock bearing 8.5 per cent iron and 11.0 per cent manganese are present to an excavation depth of 80 m.

The ferruginous and manganiferous slates are stratigraphically confined to the Smyrna Mills Formation (Hamilton-Smith

1972). The distribution of the formation in the Juniper-Knowlesville-Carlisle area is shown on the accompanying maps.

Gold and silver are reported to occur in sheared greywacke and slate east of the Knowlesville Fault, 0.6 km north of the east-trending road at South Knowlesville in I-17 map-area (Anderson 1968; Dawson 1901, p. 150). Anderson visited the abandoned pit and found only disseminated pyrite.

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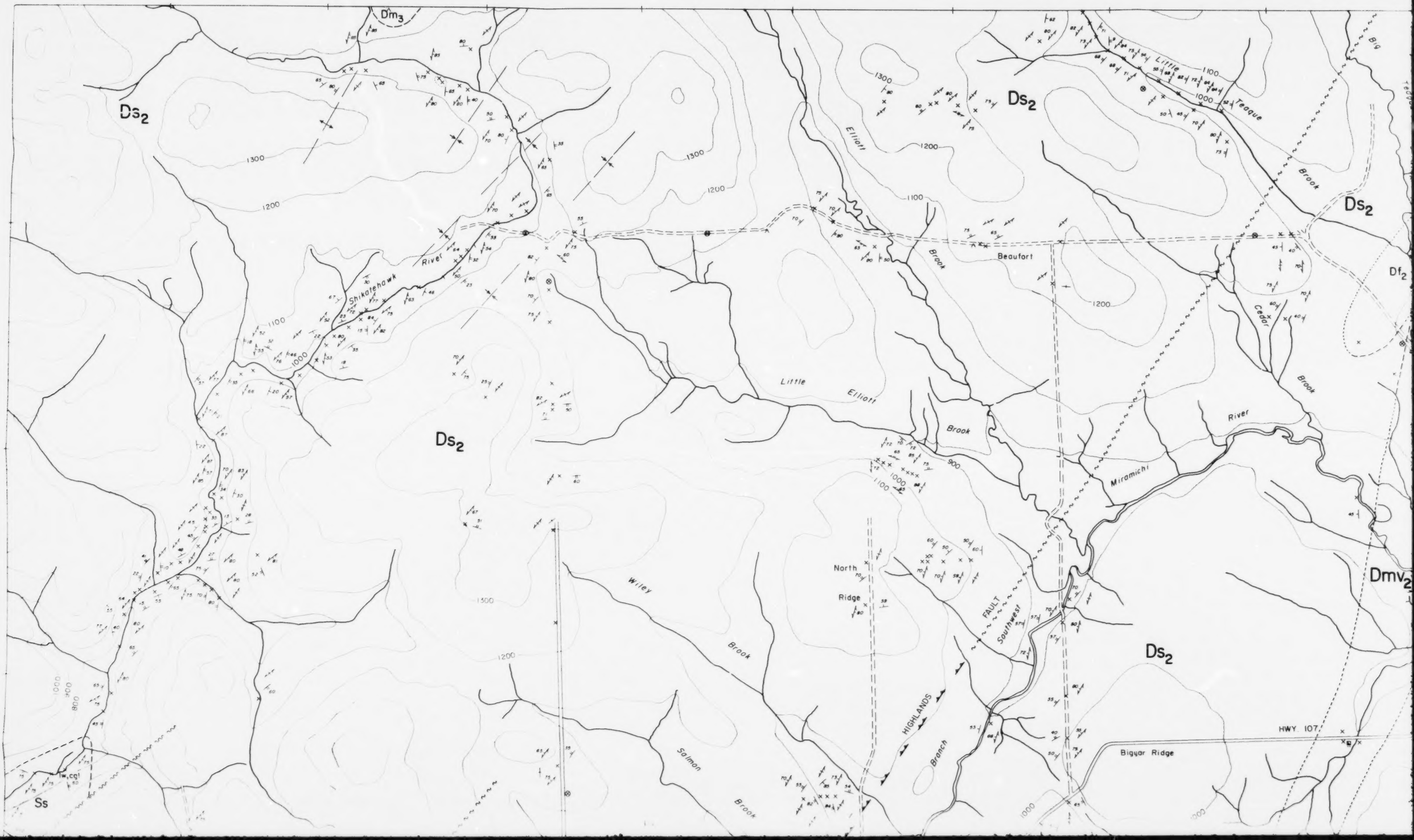
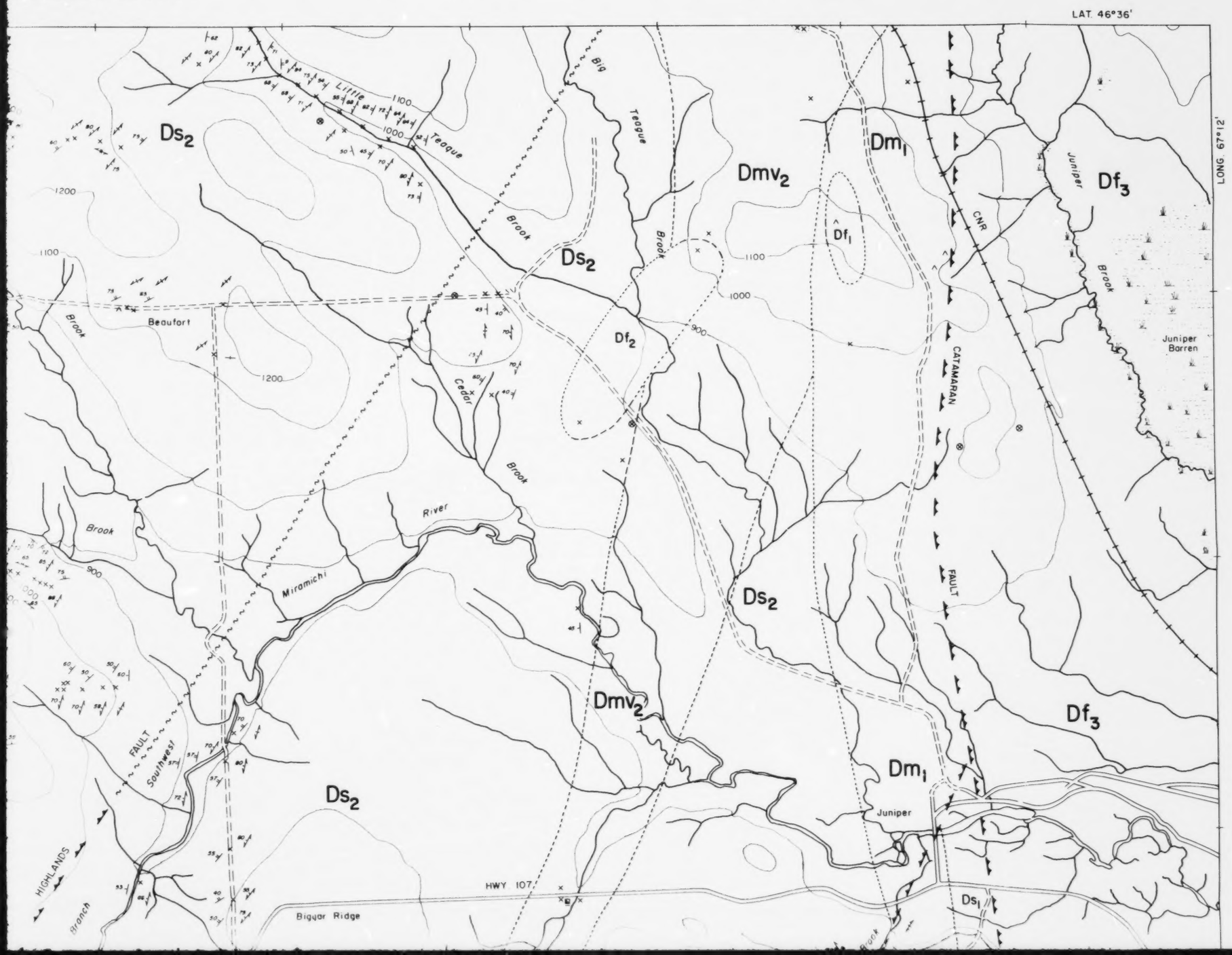
NLC

ARGYLE - JUNIPER
CARLETON COUNTY



GYLE - JUNIPER
ARLETON COUNTY

PLATE 80-35 A



DEVONIAN

Juniper Barren Granite

Df_3 — *Pink and grey, medium- grained, biotite granite*

Df_2 — *Pink to grey, biotite- quartz- feldspar porphyry, pink, fine- grained monzogranite and quartz monzonite, minor monzodiorite*

Df_1 — *Light grey, medium- grained granodiorite containing xenoliths of hornfelsic siltstone and sandstone*

Dm_3 — *Dark grey, fine- grained, diabasic gabbro; minor quartz diorite* (qd)

Becaguimec Lake Gabbro

Dm_1 — *Mottled dark green and white, medium- grained, subophitic gabbro, minor granodiorite veins* (gd), *(includes mylonitic equivalents)*

LOWER DEVONIAN

TOBIQUE GROUP

Wapske Formation

Ds_2 / Dmv_2 — Ds_2, *interbedded dark grey siltstone, dark grey slate, grey, fine- to coarse- grained sandstone, and minor polymictic conglomerate*

Dmv_2, *dark green, amygdaloidal mafic volcanic rocks, minor sedimentary rocks*

Costigan Mountain Formation

Dfv / Ds_1 — Ds_1, *dark grey siltstone interbedded with grey, fine- to medium- grained quartzose sandstone; minor dykes and sills of gabbro* (gb) *and grainodiorite* (gd)

Dfv, *pink, subtrachytic feldspar- and quartz- feldspar porphyry; minor eutaxitic rhyolitic tuff*

SILURIAN

Smyrna Mills Formation

Ss — *Green slate, green and grey, fine- grained, calcareous sandstone, green and grey siltstone; minor green nodular siltstone, red slate, grey lithic wacke* (lw), *and pebble conglomerate* (cgl)

UPPER ORDOVICIAN - LOWER SILURIAN

Carys Mills Formation

OSs — *Thinly interbedded light grey, arenaceous limestone and dark grey calcareous slate*

LOWER ORDOVICIAN

Of — *Mottled pink and grey, fine- grained, mylonitic granite*

Om — *Dark green and light grey, banded amphibolite*

CAMBRIAN - ORDOVICIAN

€Op — *Mottled light and dark grey, medium- grained, cataclastic paragneiss*

Bedding, tops known (inclined, overturned)

Bedding, tops unknown (inclined, vertical)

Ds2

Ss

Ds2

Ds2

Ds2

Ds2

Ss

Ss

Ds2

Dmv2

Ds2

Ss

OSs

Ds2

Ds2

Ds2

Dmv2

Dm3

Ds2

Dmv2

Df2

Dm3

Ds2

HIGHLANDS

Salmon Brook

ASHLAND

Lake Brook

South Branch

Beaver Brook

HWY 107

Bigger Ridge

Foreston

FAULT

Argyle

KNOWLESVILLE

South Ridge

Elder Brook

East Glassville

LONG 67°24'

LAT 46°30'

1400

1300

1200

1100

1000

1000

1100

1200

1300

1400

1000

1000

1200

GOVERNMENT OF CANADA
REGIONAL ECONOMIC EXPANSION

MILES 1 0 1 2 MILES

KILOMETRES 1 0 1 2 KILOMETRES

A

1000'

0'

Ds2

Ds2

Ss

Ds2

Ss

Ds2

Dmv2

Dm3

Dm1

ASHLAND-HIGHLANDS FAULT

Lake Brook

KNOWLESVILLE FAULT

Elder Brook

HOWARD BROOK FAULT

Dfv

HIGHLANDS Branch

HWY 107

Bigger Ridge

Beaver Brook

Simpson Brook

FAULT

HOWARD BROOK

BRADLEY MTN.

Elder Brook

South Ridge

1000 1200 1300 1400 900

Ds_2 Ds_1 Dmv_2 Df_2 Dfv Dm_3 Dm_1 Df_3 Df_1 Dm_2 ϵOp Om Of

gd gb

A A'

2 MILES

0 2 KILOMETRES

NEW BRUNSWICK DEPARTMENT OF NATURAL RESOURCES

ϵOp Mottled light and dark grey, medium-grained, cataclastic paragneiss

Bedding, tops known (inclined, overturned)

Bedding, tops unknown (inclined, vertical)

Primary flow structure in volcanic rocks (inclined)

S_1, slaty or fracture cleavage (inclined, vertical)

Axial plane of kink fold F_2 (inclined, vertical)

Cataclastic foliation (inclined, vertical)

Rock outcrop, area of outcrop, probable outcrop, float

Geological boundary (approximate, assumed)

Fault (approximate, assumed)

Reverse or thrust fault (approximate) teeth in direction of dip

Anticline (approximate trace of axial surface)

Syncline (approximate trace of axial surface)

Shaft (abandoned)

Line of section

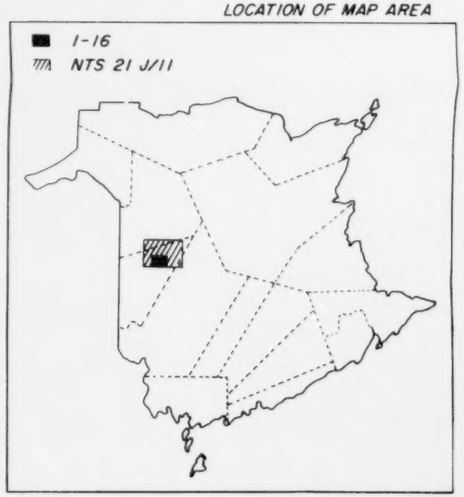
Schematic trace of bedding

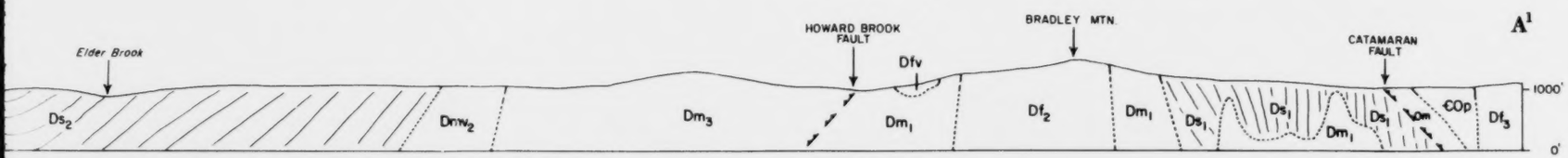
Geology by C. St. Peter, 1979 (revised Sept. 1981)

1000 Topographic contour
Contour interval 100 feet
Elevation in feet above Mean Sea Level

LOCATION OF MAP AREA

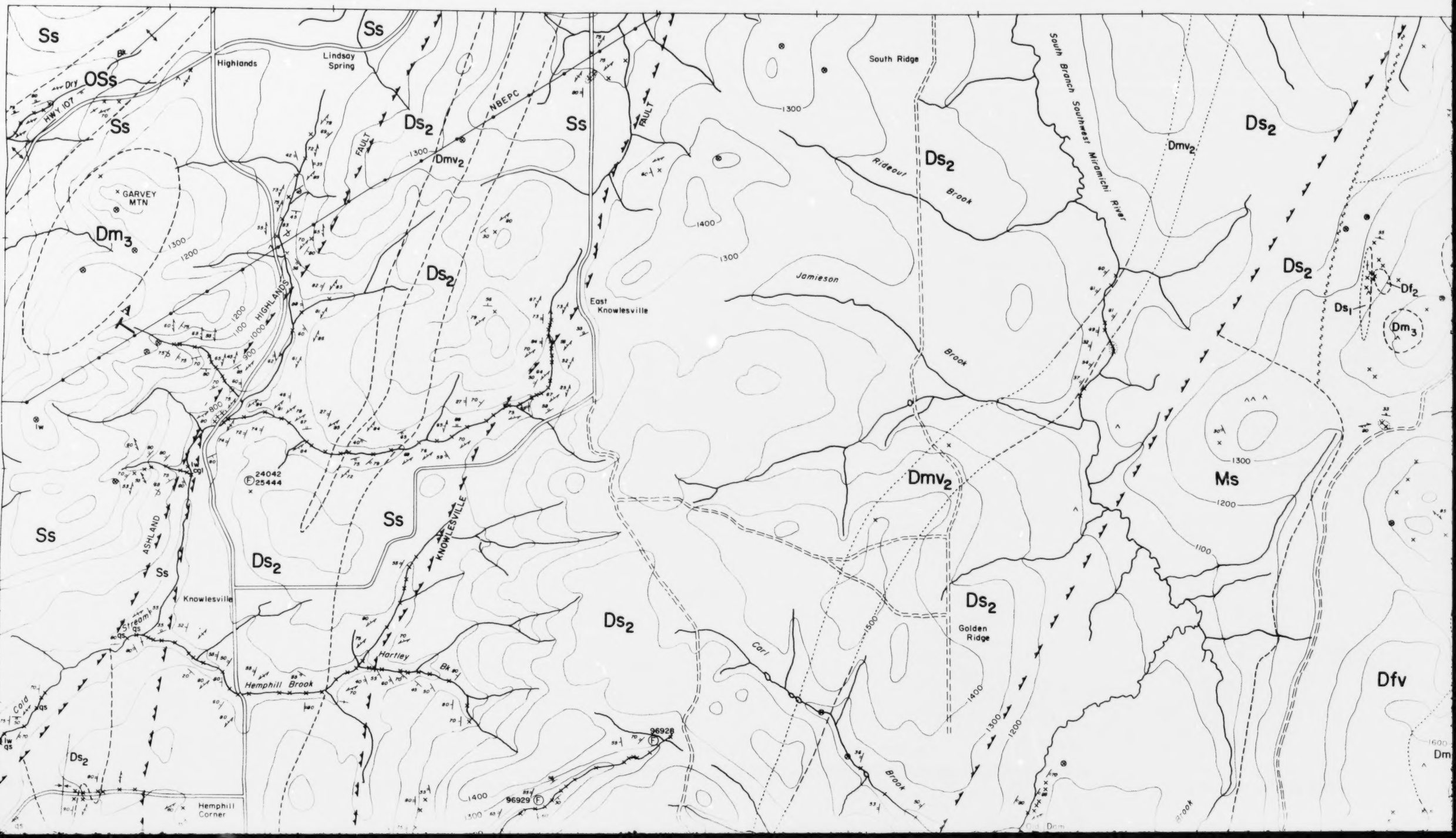
1-16
NTS 21 J/11





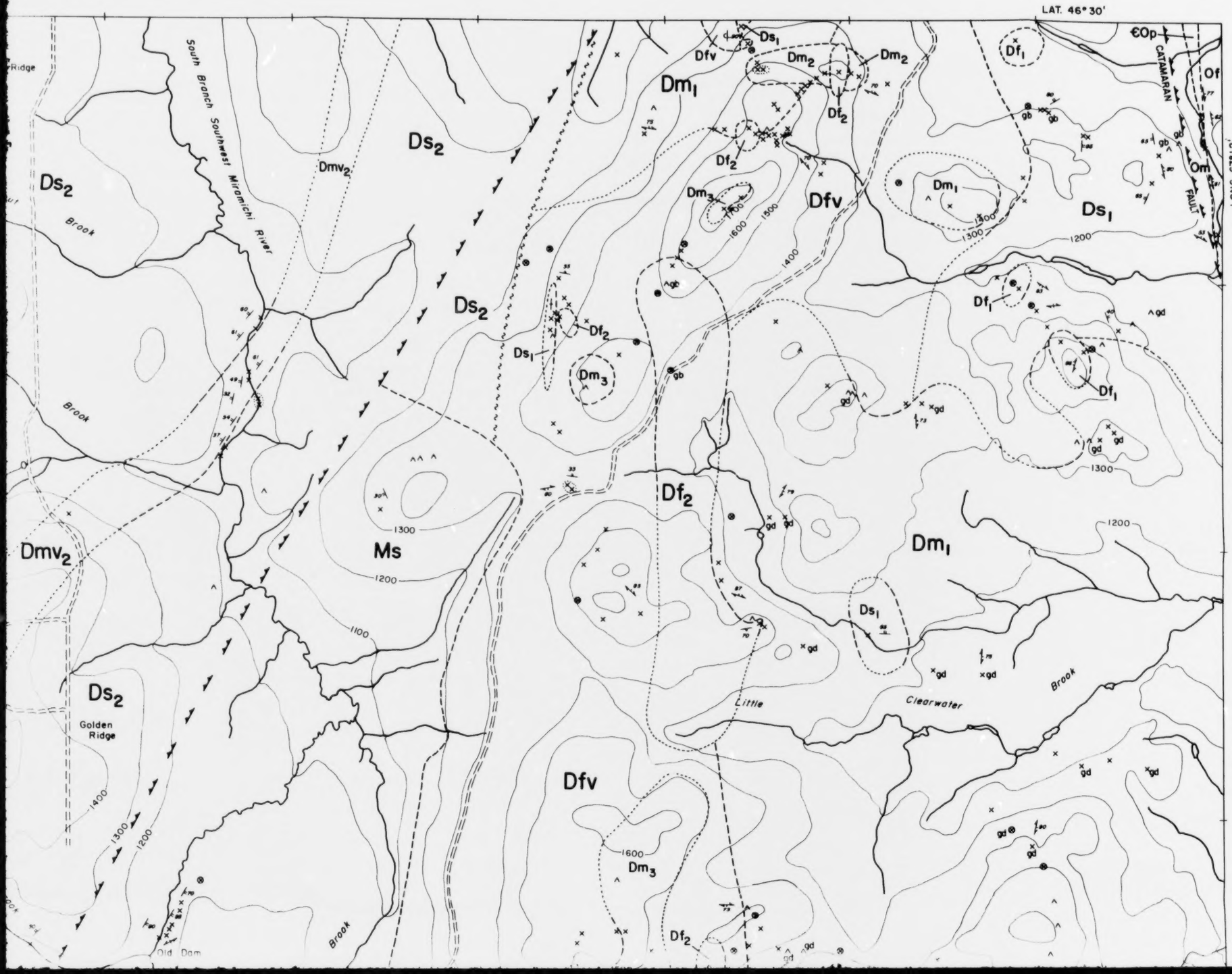
KNOWLESVILLE - ARMOND

CARLETON COUNTY



ESVILLE - ARMOND
CARLETON COUNTY

PLATE 80-36 A



MISSISSIPPIAN

Carlisle Formation

Ms — *Red, polymictic conglomerate and red, friable, medium- grained to granular lithic sandstone*

DEVONIAN

Df_2 — *Pink, fine- to medium- grained monzogranite and quartz monzonite, pink to light grey biotite- quartz- feldspar porphyry; minor gabbro xenoliths* (gb)

Df_1 — *Light grey, medium- grained granodiorite containing xenoliths of hornfelsic siltstone and sandstone*

Dm_3 — *Dark grey, fine- grained, diabasic gabbro; minor rhyolite xenoliths* (rt) *and granodiorite veins* (gd)

Dm_2 — *Grey and pink, medium- grained monzodiorite*

Becaguimec Lake Gabbro

Dm_1 — *Dark green and white, medium- grained, subophitic gabbro; minor granodiorite veins* (gd), *(includes mylonitic equivalents)*

LOWER DEVONIAN

TOBIQUE GROUP

Wapske Formation

Ds_2 / Dmv_2 — Ds_2, *dark grey slate and siltstone interbedded with grey, fine- to coarse- grained sandstone; minor grey polymictic conglomerate*

Dmv_2, *dark green, amygdaloidal, mafic volcanic rocks; minor sedimentary rocks*

Costigan Mountain Formation

Dfv / Ds_1 — Ds_1, *dark grey siltstone interbedded with grey, fine- to medium- grained quartzose sandstone, minor gabbro* (gb) *and granodiorite* (gd)

Dfv, *pink, subtrachytic feldspar – and quartz- feldspar porphyry; minor pink, lapilli, rhyolitic tuff and eutaxitic rhyolitic tuff*

SILURIAN

Smyrna Mills Formation

Ss — *Green slate, green and grey siltstone, green and grey, fine- grained, calcareous sandstone; minor green nodular siltstone; red slate; dark grey graptolitic siltstone; orange- weathering, calcareous, quartzose siltstone, green, medium- grained, quartzose sandstone* (qs); *coarse- grained, lithic wacke* (lw); *polymictic conglomerate* (cgl); *and felsic volcanic rock* (fv)

UPPER ORDOVICIAN - LOWER SILURIAN

Carys Mills Formation

OSs — *Thinly interbedded light grey, arenaceous limestone and dark grey, calcareous slate*

LOWER ORDOVICIAN

Of — *Mottled pink and grey, fine- grained, mylonitic granite*

Om — *Dark green and light grey, banded amphibolite*

CAMBRIAN – ORDOVICIAN

€Op — *Mottled light and dark grey, medium- grained, cataclastic paragneiss*

LONG 67°24'

LAT 46°24'

Hemphill Corner

Armond

South Knowlesville

Old Dam

FAULT

ARMOND FAULT

KNOWLESVILLE FAULT

HOWARD BROOK FAULT

Hamilton Brook

Howard Brook

Upper Howard Brook

Lower Howard Brook

Macintosh Brook

Tomarac Brook

SKEDADDLE RIDGE

Brighton

FT

96928 96929 96930 96931 96932 96933 96934 96935 96936 96937 96938

Ss Ds$_2$ Dm$_3$ Dmv$_2$ Ms Dfv Ds$_1$

MILES 0 1 2

KILOMETRES 0 1 2 KILOMETRES

GOVERNMENT OF CANADA REGIONAL ECONOMIC EXPANSION

A

ASHLAND-HIGHLANDS FAULT

Fall Brook

KNOWLESVILLE FAULT

HOWARD BROOK FAULT

Mac Intosh Brook

1000'

0'

Om — Dark green and light grey, banded amphibolite

CAMBRIAN – ORDOVICIAN

€Op — Mottled light and dark grey, medium- grained, cataclastic paragneiss

Bedding, tops known (inclined, vertical, overturned)

Bedding, tops unknown (inclined, vertical)

Primary flow structure in volcanic rocks (inclined)

S_1, slaty or fracture cleavage (inclined, vertical)

Cataclastic foliation (inclined, vertical)

Rock outcrop, area of outcrop, probable outcrop, float

Geological boundary (approximate, assumed)

Fault (defined, approximate, assumed) arrows indicate relative movement

Reverse or thrust fault (approximate) teeth in assumed direction of dip

Anticline (approximate trace of axial surface)

Syncline (approximate trace of axial surface)

F 96932 — Fossil locality with G.S.C. index number

Quarry (abandoned)

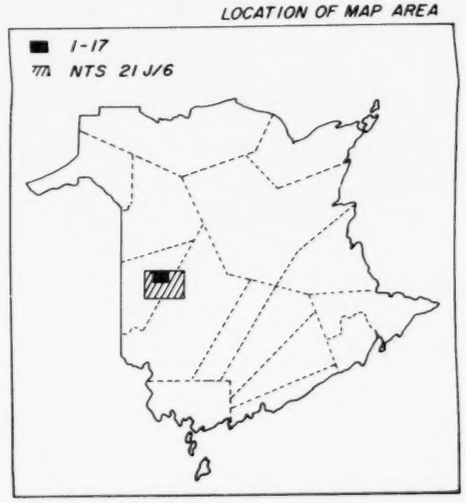
A — A' Line of section

Schematic trace of bedding

Geology by C. St. Peter, 1979 (revised Sept, 1981)

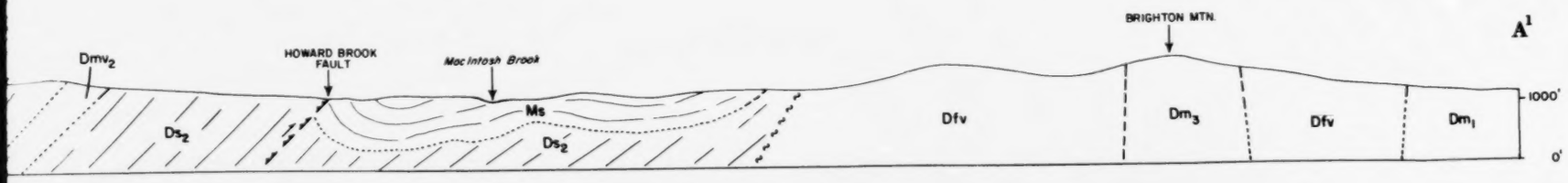
1000 — Topographic contour
Contour interval 100 feet
Elevation in feet above Mean Sea Level

LOCATION OF MAP AREA



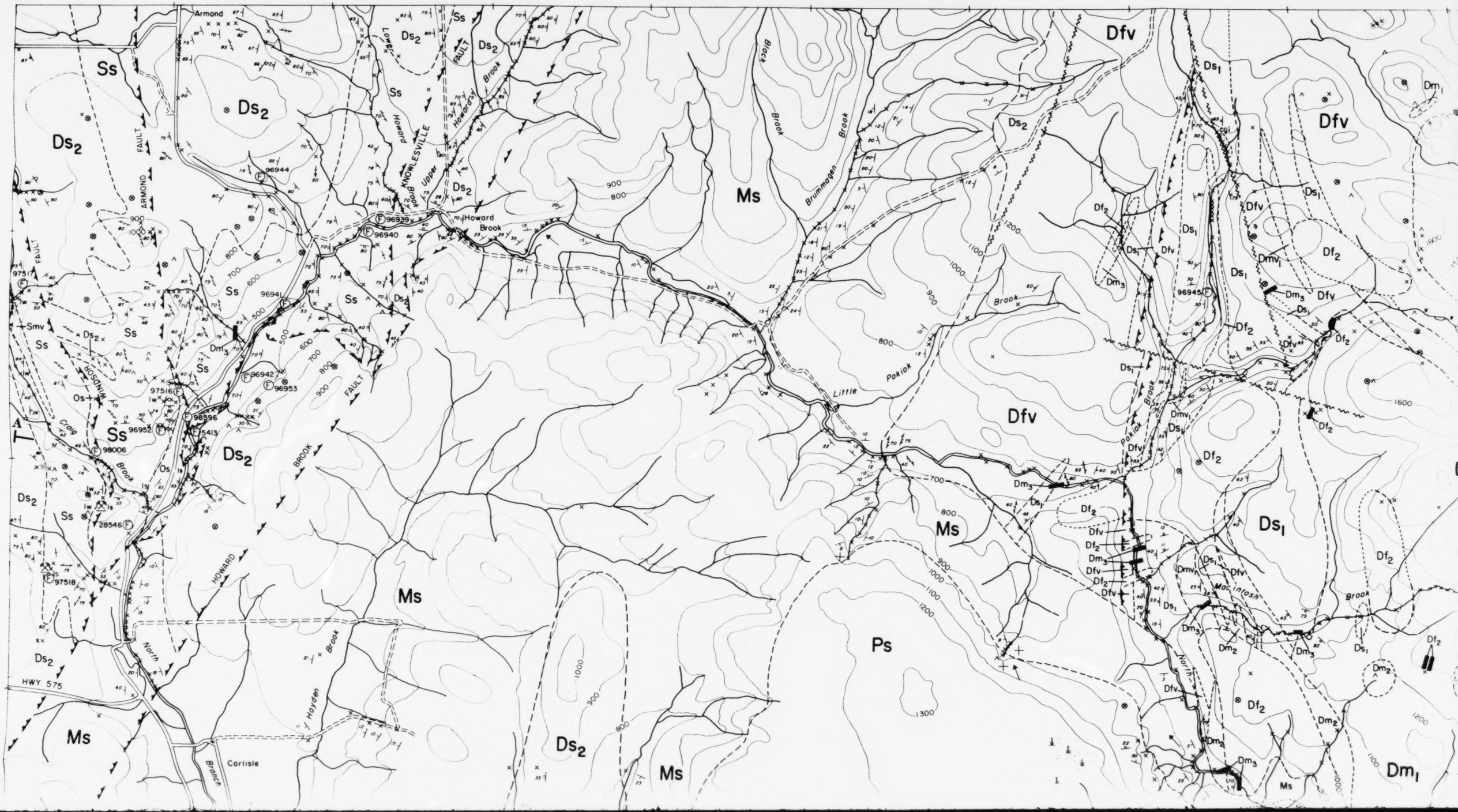
0 1 2 KILOMETRES

NEW BRUNSWICK DEPARTMENT OF NATURAL RESOURCES



NORTH BRANCH BECAGUIMEC - CARLISLE - CLOVERDALE

CARLETON & YORK COUNTIES



IMEC - CARLISLE - CLOVERDALE
ON & YORK COUNTIES

PLATE 80-37 A

LAT. 46°24'

LONG. 67°12'

River

Noshwaak

West

Doughboy Lake

Doughboy Brook

Little Doughboy Lakes

Malcolm Lake

Silver Lakes

Long Lake

Cedar Lake

Mud Lake

Brook

Pokiok Brook

North Branch

Mac intosh Brook

96945 (F)

A¹

PENNSYLVANIAN

Mountain View Formation

Ps — *Grey quartzose sandstone and quartz-pebble conglomerate*

MISSISSIPPIAN

Carlisle Formation

Ms — *Red, polymictic conglomerate; red friable, medium-grained to granular lithic sandstone; minor red mudstone, red breccia and grey arkose*

Unnamed Formation

Mmv — *Dark grey, amygdaloidal mafic volcanic rocks*

DEVONIAN

Df_2 — *Pink, fine- to medium-grained monzogranite and quartz monzonite, pink biotite-quartz-feldspar porphyry; minor pink microgranite and quartz monzodiorite*

Dm_3 — *Dark grey, fine-grained, diabasic gabbro*

Dm_2 — *Grey and pink, medium-grained monzodiorite*

Becaguimec Lake Gabbro

Dm_1 — *Dark green and white, medium-grained, subophitic gabbro, minor gabbro pegmatite* (pg)

LOWER DEVONIAN

TOBIQUE GROUP

Wapske Formation

Ds_2, Dmv_2 — Ds_2, *dark grey siltstone interbedded with grey, fine- to coarse-grained sandstone and grey polymictic pebble-cobble conglomerate*; Dmv_2, *dark green, amygdaloidal, mafic volcanic rocks*

Costigan Mountain Formation

Dmv_1, Dfv, Ds_1 — Ds_1, *interbedded dark grey siltstone and light grey quartzose sandstone; minor conglomerate* (cgl); Dmv_1, *dark green, amygdaloidal, mafic volcanic rock; minor sedimentary rocks*; Dfv, *pink, subtrachytic feldspar- and quartz-feldspar porphyry, pink, lapilli rhyolitic tuff; minor eutaxitic rhyolitic tuff*

SILURIAN

Smyrna Mills Formation

Ss, Smv — Ss, *green slate, green and grey siltstone, green, fine-grained, calcareous sandstone; minor red slate, green nodular siltstone, dark grey, graptolitic siltstone, orange-weathering, calcareous quartzose siltstone, grey lithic wacke* (lw), *and light grey limestone* (ls); Smv, *dark green, amygdaloidal, mafic volcanic rocks*

MIDDLE ORDOVICIAN

Craig Brook Limestone

Os — *Grey lithographic limestone and crystalline limestone, dark grey chert and calcareous slate; minor quartzose sandstone and dolomite*

Bedding, tops known (inclined, vertical, overturned, horizontal)

Bedding, tops unknown (inclined, vertical)

Primary flow structure in volcanic rocks (inclined, vertical)

S_1, slaty or fracture cleavage (inclined, vertical)

Ms
Carlisle
Branch
Mainstream
HWY 575
Becaguimec
Northville
23997
96948
River
Ds2
Dmv2
Jericho
96946
Cloverdale
Ds2
Ms
96950
96947
96949
Day Brook
Fall Brook
Mountain View
96951
Ps
Black Brook
Dm2
Dm3
Dm1
Mmv
Lake
Df2
Becaguimec River
LONG 67°24'
LAT 46°18'
GOVERNMENT OF CANADA
REGIONAL ECONOMIC EXPANSION
MILES 1 0 1 2 MILES
KILOMETRES 1 0 1 2 KILOMETRES

A
WINDSOR FAULT
North Branch Becaguimec River
HOWARD BROOK FAULT
Hayden Brook
Ps
Ms
Dfv
Ds1
Df2
Dm2
500'
0'
-500'

Bedding, tops known (inclined, vertical, overturned, horizontal)

Bedding, tops unknown (inclined, vertical)

Primary flow structure in volcanic rocks (inclined, vertical)

S_1, slaty or fracture cleavage (inclined, vertical)

Cataclastic foliation (inclined, vertical)

Sediment transport direction

Minor fold (axis inclined)

Rock outcrop, area of outcrop, probable outcrop, float

Geological boundary (approximate, assumed)

Fault (approximate)

Reverse or thrust fault (approximate) teeth in direction of dip

Syncline (approximate trace of axial surface)

F 96951 Fossil locality with G.S.C. index number

Dyke

Quarry (abandoned)

A — A' Line of section

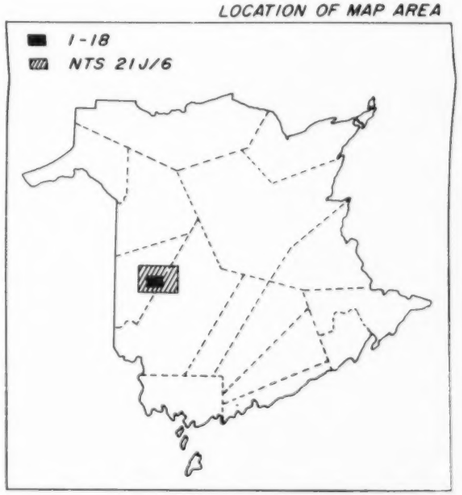
Schematic trace of bedding

Geology by C. St. Peter, 1979 (revised Sept. 1981)

1000 Topographic contour
Contour interval 100 feet
Elevation in feet above Mean Sea Level

LOCATION OF MAP AREA

1-18
NTS 21J/6



2 MILES
2 KILOMETRES

NEW BRUNSWICK DEPARTMENT OF NATURAL RESOURCES